Uncertainty Handling in Mobile Community Information Systems

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Diplom-Informatikerin
Yiwei Cao

aus Shanghai, China

Berichter: Universitätsprofessor Dr. rer. pol. Matthias Jarke
Prof. Dr. (Catedrático) Baltasar Fernández-Manjón
Privatdozent Dr. rer. nat. Ralf Klamma

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Kurzfassung

Gegenwärtige mobile Informationssysteme für Praxis-Gemeinschaften (Community of Practice, CoP) verarbeiten gewaltige Mengen an Multimedia, bieten mannigfaltige Kommandos zum Verarbeiten von Multimedia und bedienen diverse Praxis-Gemeinschaften, die unterschiedliche mobile Geräte nutzen. Ungenaue oder sogar falsche GPS-Daten, fehlerhafte semantische Beschreibungen von Multimedia durch Benutzer oder unterschiedliche Interpretationen von Multimedia in verschiedenen Praxis-Gemeinschaften führen zu unsicheren Daten. Das Thema Datenunsicherheit wurde im Forschungsgebiet "advanced uncertainty databases" mit Ansätzen aus der Wahrscheinlichkeitstheorie, Analyse der Datenherkunft (data lineage) und Fuzzy-Logik bearbeitet. Allerdings behandeln diese Ansätze nur traditionelle Datenunsicherheitsprobleme in Datenbanken; sowohl Multimedia als auch Einflüssen von Benutzern und Praxis-Gemeinschaften wurde wenig Aufmerksamkeit geschenkt. Beide Aspekte sind jedoch wichtig zum Datenmanagement in den weit verbreiteten webbasierten sowie mobilen Informationssystemen für Praxis-Gemeinschaften. Deshalb adressiert diese Dissertation das Problem unsicherer Daten unter besonderer Beachtung des sich schnell entwickelnden Web 2.0 und der zunehmend genutzten mobilen Technologien. Die in mobilen Informationssystemen für Praxis-Gemeinschaften neu entstandene Datenunsicherheit wird in meiner Dissertation als Unsicherheit 2.0 definiert, bezüglich der Aspekte Kontext, Multimedia und Praxis-Gemeinschaft.

Um die Probleme mit unsicheren Daten bearbeiten zu können, habe ich ein Modell entwickelt, das die Aspekte Kontext- und Semantik-Management sowie Praxis-Gemeinschaften zusammenführt. Gemeinsames Annotieren (collaborative tagging) von Multimedia und Geschichten erzählen in Praxis-Gemeinschaften (community-based storytelling) sind die Hauptansätze, um Unsicherheit 2.0 zu behandeln und das Entwickeln von mobilen Informationssystemen für Praxis-Gemeinschaften zu unterstützen. Dieses Modell gründet auf zwei Annahmen: Erstens, Interaktion und Konvertierung zwischen Kontext und Semantik von Multimedia sind entscheidend für mobiles und webbasiertes Datenmanagement in mobilen Informationssystemen für Praxis-Gemeinschaften. Zweitens, die Adaption des Konzepts "Praxis-Gemeinschaft (CoP)" bietet großes Potenzial, um die durch unsichere Daten entstehenden Probleme zu reduzieren. Die von den Praxis-Gemeinschaften genutzten Praktiken im Umgang mit Multimedia sind gemeinsames Annotieren und Geschichten erzählen. Diese Praktiken ermöglichen den Zugriff auf die Nutzung von Expertise der Praxis-Gemeinschaft und reduzieren die Unsicherheit 2.0. Amateure sind dadurch in der Lage Wissen in Praxis-Gemeinschaften zu erarbeiten und entsprechende Erfahrungen zu machen. In den Bereichen Denkmalpflege und technologiegestütztem Lernen wurden eine Reihe von Anwendungen entwickelt, die auch genutzt wurden, um die Modelle und Ansätze zur Behandlung von Unsicherheit 2.0 zu validieren.

Abstract

Current mobile community information systems handle vast amounts of multimedia, various operations on multimedia processing, and diverse user communities using different mobile devices. Imprecise or even false GPS information, users' false semantic description about a multimedia artifact, or different interpretations of multimedia content in different user communities lead to data uncertainty. Some research work has been conducted in advanced uncertainty databases with probabilistic theories, data lineage, and fuzzy logic. However, these approaches deal with "conventional" data uncertainty problems at the database level. Multimedia content as well as user and community factors are not paid much attention, which is important for data management in prevalent web and mobile community information systems. Hence, this dissertation deals with data uncertainty problems addressed with the emerging and advanced development of Web 2.0 and mobile technologies. In my research I identify the new uncertainty problem perspectives in context, multimedia semantics, and community in mobile community information systems, namely *uncertainty 2.0*.

To deal with this uncertainty 2.0 problem, I have developed a model with a combination of the aspects of context management, semantics management, and community of practice realization. Collaborative tagging for multimedia content and community-based storytelling are the key approaches to handling uncertainty problems and engineering mobile community information systems. This model is established with two foci. First, interactions and conversions between multimedia semantics and multimedia context are crucial for mobile and Web data management in mobile community information systems. Second, development of the concept *community of practice* has great potentials to reduce uncertainty 2.0 problems. The *practices* taken by communities consist of multimedia tagging and multimedia storytelling. Amateurs are able to develop their knowledge and experiences in communities of practice. Uncertainty is reduced via this cultivation of expertise with the help of community of practice. A set of mobile community information system applications have been realized in the domains of cultural heritage management and technology enhanced learning, which validates the models and approaches to uncertainty 2.0 handling.

I can no other answer make, but, thanks,
and thanks.

William Shakespeare

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Words may be too superfluous to express my gratitude at this moment. I'd like to use the simplest words to say the deepest thanks to all.

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Yiwei Cao, Aachen, March 22, 2012

Contents

Information is not knowledge. ...
The only source of knowledge is experience.

Albert Einstein

Chapter 1

Introduction

This dissertation deals with data uncertainty problems and modeling, where a comprehensive combination of approaches focusing on the aspects of multimedia semantics, context, and communities is used. The recent technical and social progress in information systems, mobile technologies, multimedia technologies, and the Web has been changing the conventional understanding of *community information systems*. The means for multimedia production and consumption are changing, and community users are involved in systems intensively. The technology innovations lead to complex community information systems with vast amounts of multimedia, various operations for multimedia processing, and diverse user communities using different devices. In my research I identify a new uncertainty problem in data management both for the Web and for mobile community information systems, namely *uncertainty 2.0*. An uncertainty 2.0 handling model is proposed with two foci. First, interactions and conversions between multimedia semantics and context are introduced for mobile and web data management. Second, development of the concept *community of practice* for mobile and Web is adapted to reduce uncertainty 2.0 problems. The proposed model enables "amateurs" to develop their personal knowledge and expertise for multimedia processing and become "experts" in the environments of community of practice. Furthermore, the model integrates *practices* taken by communities such as multimedia tagging and multimedia storytelling, which cover semantic, context, and community aspects. In addition, mobile and web-based community information systems have been developed to validate the concepts of the model.

The main contributions of this dissertation include formulation of uncertainty 2.0 problems and their causes, development of a data management model combining multimedia semantics and context, and specification and development of the models and approaches for multimedia tagging and storytelling in communities.

1.1 Motivation and Background

Data uncertainty is a broad interdisciplinary research area. The sources of data uncertainty in mobile community information systems are manifold. Imprecise or even false GPS information, users' false semantic description about a multimedia artifact, or different interpretations of multimedia content in different user communities lead to data uncertainty problems. The problems include that users cannot find the multimedia content in their own collections or cannot share multimedia with their communities. Creation and sharing multimedia on mobile devices need context information processing. Different user communities with different domain knowledge background may have different understandings of the same multimedia artifacts.

For example, if we look at the user communities of cultural heritage management, the community members are experts in architecture, archeology, and history. Their research work may be conducted on site at historical buildings or monuments, while they also work on piles of paper documents on the table and on various digitalized multimedia documents. With the rapid development of multimedia technologies, they use different computing devices such as smartphones, notebooks, and various kinds of cameras. These cultural heritage domain experts might be multimedia amateurs in capturing and handling multimedia artifacts. Thus, they work with other researchers and engineers even from other disciplines such as computer scientists collaboratively.

Interdisciplinary collaboration between domain experts (who might be multimedia amateurs) and multimedia experts addresses new challenges for mobile community information systems. For example, a multimedia expert representative, a photographer, takes a lot of pictures and videos of Aachen Cathedral and gives annotations to the multimedia documents for online sharing. A cultural heritage management expert who has never been in the city Aachen may search for Aachen Cathedral related multimedia documents for the purpose of research, teaching, or publications. However, it is not so simple for a cultural heritage management expert to get a satisfying picture because of the following data uncertainty issues for instance:

- The pictures may have missing or wrong time information. For example, if they both ask for pictures of sunset time, it could be hard to differentiate the pictures from the sunset or other time without accurate temporal context information. We call this kind of uncertainty *context uncertainty*.
- The pictures may have the GPS coordinates information with a wrong location name. For example, domain experts are not able to find the pictures based on location search by a given location name. The semantics embedded in the context information is uncertain. We call this kind of uncertainty *semantics uncertainty*.
- Various motifs on the stained glass windows may be described with different semantic information by the photographer and by the domain expert having different community

backgrounds. For example, the domain expert may look for a special story told in a stained glass window, while this semantic information is totally incomparable or missing as the photographer tags the related pictures. We call this kind of uncertainty *community uncertainty*.

Existing data uncertainty research addresses uncertainty in a large amount of data coming from scientific and social experiments. Textual and numerical uncertain data is identified as wrong/*incorrect* information, *imprecise* information, *incomplete* information, or *inconsistent* information (*4I*) [KKMK09]. The handling approaches are closely connected with probabilistic theories [CuFr99], data lineage [BSHW06], fuzzy logic [Schn99], and advanced uncertainty databases [SBHW06, SMM*08]. These approaches have dealt with "conventional" *4I* data uncertainty problems in databases and made much progress especially in theoretical research. However, there still exist research gaps, when uncertainty problems in mobile community information systems are considered.

From the perspective of recent practical achievements in information systems, Web 2.0 and mobile systems together open massive multimedia production and consumption channels for users. Besides *information creation*, one of the goals of information production is to be "sold" to users. Various users' activities such as tagging, rating, sharing, and recommending push multimedia resources to a large number of users. Mobile technologies are accelerating this digitization process of information production and consumption. Smartphones are used more frequently for other purposes than calling, and enable users to create, produce, consume, and share multimedia on the fly.

Consequently, the technology innovations lead to complex *community information systems* with vast amounts of multimedia, various multimedia processing operations, and diverse user communities using different mobile devices. The resulting data uncertainty problems are connected with multimedia content in mobile environments and influenced by user communities intensively. Hence, it is not adequate to handle uncertainty only with probabilistic database technologies. Multimedia content as well as user and community factors have to be considered in data uncertainty problem formulation. Frameworks and models are required to engineer mobile community information systems for uncertainty issues.

This dissertation handles data uncertainty problems, named *uncertainty 2.0*, caused by heterogeneous multimedia repositories especially from Web 2.0 and mobile applications. In such (mobile) multimedia environments with many users' interactions, contextual information varies, and multimedia semantics is ambiguous. The solutions come along with the perspectives where the problems are raised. On the one hand, community users from social software and Web 2.0 create data uncertainty. But users are potentially able to reduce data uncertainty as well, if some collaborative data quality enhancement measures are taken. For instance, users' trustful interaction on systems such as multimedia tagging can be enhanced via users' role models and role management. On the other hand, multimedia semantics and context should not be considered and dealt with as two separate information aspects. The transformation processes between semantics and context can help reduce multimedia uncertainty through the "double-checking" of context and semantic information. Thus, the aspects of semantics and context, and communities are considered to be the basis of my approach to uncertainty handling.

1.2 Research Questions

The research challenges in my dissertation come from uncertainty embedded in rich multimedia content on Web 2.0, uncertainty in mobile environments, and users' impacts on web and mobile applications. Besides the existing research results in advanced uncertainty databases, it is still challenging to formulate uncertainty in mobile community information systems. In this dissertation, data uncertainty in mobile community information systems is related to the following three problem aspects:

Semantics uncertainty

Data uncertainty problems are raised by multimedia semantics. *Semantics* as a concept for information imparting is rich albeit uncertain. Different users may have different interpretations and understandings. On Web 2.0, tagging has been often applied to attach semantic information to multimedia content. However, user-generated tags are uncertain as well. For example, in the social network site for music Last.fm there exist at least two crucial elements: music pieces and their interpreters. If a tag of a name is attached, this may refer to a person who has written the song, a person who sings the song, a person who is the DJ, or a person who has uploaded the song. All these queries embrace rich semantic information which can be judged by humans much better than by machines. Since tags are applied widely for semantics management, can we optimize usage of tags to reduce uncertainty in mobile community information systems?

Context uncertainty

Data uncertainty in mobile multimedia information systems is related to location and temporal information, users' intention, and mobile multimedia creation and sharing at any time anywhere. All this information belongs to context information. Context is any information that can be used to characterize the situation of an entity [Dey01]. All information about users' physical and social environment is context information. Some technical information about mobile multimedia is context information as well. The context itself is uncertain because errors may occur while context information is collected. For example, users upload pictures with location information which was captured by smartphones wrongly. Wrong contextual information leads to wrong semantic understanding. What information processes may operate on multimedia semantics and context for uncertainty handling?

Community uncertainty

A community consists of users who share similar interest, in the context of the concept of *Community of Practice*. *Communities of Practice* are groups of people who share a concern or a passion for something they do and who interact regularly to learn how to do it better [Weng98]. If the user factor in mobile multimedia data management is taken into consideration, the community structures in mobile multimedia information systems are crucial to handle data uncertainty problems. When users search for multimedia, the "right" information matching their expectations is evaluated or influenced by the communities the users belong to. Users in an architecture study community could be interested in totally different multimedia than those in a real estate business community, though they might request multimedia artifacts with the same keywords. Although multimedia artifacts are shared via YouTube or Twitter without any restriction, special requests and special processing methods of user communities are not well covered in those Web 2.0 platforms. The data uncertainty problem is raised because communities may have different expertise knowledge and different operations to convey information within and across communities. What media operations are useful in communities for data uncertainty reduction? How do users' roles in communities distinguish?

To elaborate and solve these uncertainty issues, five research questions are addressed:

- How to define, identify, and handle uncertainty in mobile community information systems? This question is addressed because data uncertainty problems in Web 2.0 and mobile applications are still new and have different and more complicated aspects rather than general data uncertainty problems. This research question is associated with realization of mobile community information systems. It cannot be handled alone through the existing uncertainty handling approaches, e.g. probabilistic theories.

- What information processes may combine multimedia semantics and context to handle uncertainty? This research question is addressed for uncertainty handling from basic perspectives. Semantics and context are identified as two important information types for multimedia content. Multimedia operations and information processes need to be specified to cooperate on both multimedia semantic and contextual information.

- Which roles and with which "practices" do communities of practice play? This question is raised from users' perspectives. Multimedia semantics is comprehended by users. And context information comes directly from the environments to refine users' multimedia management and search. Both semantics and context can be further processed with the impacts of user communities.

- What impacts do experts and amateurs have on uncertainty handling in mobile community information systems? What roles does community of practice play to make amateurs become experts? In communities users carry out various practices and are important action-takers for uncertainty handling. Users are different according to their profiles, knowledge, and skills, and are also able to develop themselves in communities of practice.

- Can we optimize usage of tags to reduce uncertainty in mobile community information systems? Since multimedia semantics, context, and communities are considered as important aspects for mobile community information systems, tags as a metadata type embed all these three aspects of information. Tags should be beneficial to engineer and develop mobile community information systems.

1.3 Approaches and Contributions

Starting from the previous research challenges, I combine Web 2.0 and mobile applications with *community information systems* which work for professional user communities instead of the heterogeneity of users across the Web 2.0 platforms. The ATLAS media theory [Jaeg02, Span07, Klam10] has established a sound foundation for community information systems. These already systematically-developed approaches from community information systems are brought onto web and mobile data management. In addition, new concepts and models from Web 2.0 and mobile applications are integrated into conceptualization and realization of mobile community information systems.

With regard to uncertainty issues in mobile community information systems, I formulate the uncertainty 2.0 problem and classify it into the aspects of semantics, context, and communities. Accordingly, a five-layer community-media model is proposed to handle uncertainty in mobile community information systems. The data uncertainty handling is analyzed from a wider layer of heterogeneous multimedia repositories, metadata, multimedia semantics and context, to the upper layer of community of practice. Related methods and solutions are discussed about how to manage multimedia semantics uncertainty, context uncertainty, and community uncertainty. The community-based media operations are proposed for (mobile) data management. The core operations can be abstracted as *semantization* and *contextualization*. Multimedia semantics and context can switch from one to the other in either of the processes.

I argue that communities of practice [Weng98] are effective to reduce data uncertainty, and to improve multimedia sharing. Two useful practices are proposed and modeled: collaborative tagging and community-based storytelling. It is important for community build-up and development to have the both practices as realization instances of the semantization and contextualization operations, which are derived from the media operations of *transcription*, *localization*, and *addressing* in the ATLAS media theory [Jaeg02, Span07, Klam10]. A media artifact is transcribed into a transcript to enhance its readability, localized and addressed to communities. Users' development from amateurs to experts is supported through the practices in communities of practice.

First, the tagging approach as a semantization process is beyond the disorder of tag clouds. The process of *tagging* is a *transcription* process, to transcribe a media artifact with tags. When contextual information is taken into consideration, a media artifact is also *localized* to a certain context. Tags have various dimensions on the Web and play an important role in engineering mobile community information systems. Tagging activities are analyzed, modeled, and formulated systematically. A multi-granular tagging model is developed

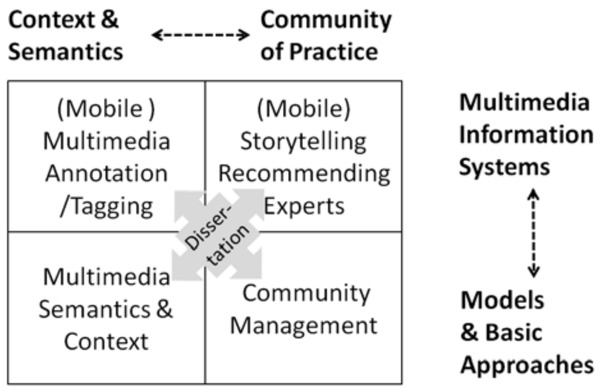

Figure 1.1: Background methodologies and research areas for data uncertainty handling

to enrich media semantic transcription at different media content levels. The dimension of communities forming up the concept "commsonomy" extends the existing tag spaces consisting of users, resources, and tags. Through this approach, users are able to exploit different multimedia operations represented in tagging. Users are also enabled to annotate multimedia resources with different approaches to reducing uncertainty. The tagging approach establishes a semantic order of multimedia and tags in order to engage user communities with better multimedia tagging interactions to reduce uncertainty.

Second, the process of *storytelling* is a *transcription* process as well, in order to enhance readability of a collection of media artifacts. Meanwhile, storytelling to certain audience communities is an *addressing* process to specific audience communities. The working mechanism of storytelling is demonstrated as an effective approach to mobile multimedia management. For uncertainty handling, users are facilitated with storytelling tools to have more control over multimedia stories. Individual multimedia artifacts are organized for certain purposes, usage, or context via this storytelling process.

As mentioned previously, the conceptualization and development of these approaches are based on existing research in community information systems. Figure 1.1 depicts the methodologies and research areas to handle uncertainty 2.0 problems. The basic models consist of multimedia semantics and context, and community management. Along the axis of multimedia information systems, multimedia annotation and tagging are useful media operations to enrich multimedia semantics and context. Multimedia storytelling involves the whole multimedia management processes with experts' impacts. These four research fields draw the outline of this dissertation.

With regard to the practical contributions, this dissertation is linked to knowledge and experiences of the German Excellence Research Cluster Ultra High-Speed Mobile Information and Communication (UMIC)[1], which is established under the German Excellence Initiative at RWTH Aachen University in Germany. UMIC aims at providing an order of magnitude

[1]http://www.umic.rwth-aachen.de

improvement of the perceived quality of mobile services for the next-decade mobile Internet on an interdisciplinary cooperative research work. Within the UMIC research cluster, a mobile application and service scenario called *Virtual Campfire (VC)* demonstrates and processes mobile community information systems for cultural heritage management communities. Mobile multimedia data management is carried out across different platforms during all user multimedia interaction processes including a series of actions: creation, annotation/tagging, adaptation, and storytelling of mobile multimedia. At the same time, uncertainty 2.0 is handled by the underlying semantization and contextualization media operations on communities of practice.

1.4 Structure of the Dissertation

Chapter 2 formulates uncertainty 2.0 and explains the terminologies related to *data uncertainty* and *mobility*. Especially, what kind of data uncertainty is dealt with in my dissertation? Motivations and problems are stressed through the exploration of sources of uncertainty 2.0, coming from the context, semantics, and community aspects.

Chapter 3 gives an overview on the state of the art in the related research areas. Existing concepts, theories, and applications about information management, community of practice, Web 2.0, multimedia semantics, context awareness, multimedia annotations, digital multimedia storytelling, and uncertainty handling are surveyed.

Chapter 4 presents a model to handle uncertainty 2.0 in the context of community-user-multimedia relationships. Uncertainty dimensions are specified in tag spaces, and a mapping model about multimedia semantics and context is proposed. A community-based semantic multimedia tagging model, so-called *commsonomy*, involves not only media and its metadata, but also the important community aspect.

Chapter 5 pertains to the approaches to handling and reducing uncertainty 2.0 through community-based storytelling. Several approaches such as non-linear storytelling, a comprehensive role model, and story templates are applied to help users create stories collaboratively. The role changes between experts and amateurs within the communities are discussed as an effective approach to uncertainty reduction.

Chapter 6 validates the models and concepts to handle uncertainty 2.0 in mobile community information systems. The scenario Virtual Campfire is realized in the application domains cultural heritage management and technology enhanced learning. The evaluation results are discussed for each application instance of mobile community information systems.

Chapter 7 draws conclusions of this dissertation and presents potential future research directions for handling uncertainty 2.0 problems.

Whether it is good or evil, whether life in itself is pain or pleasure, whether it is uncertain-that it may perhaps be this is not important-but the unity of the world, the coherence of all events, the embracing of the big and the small from the same stream, from the same law of cause, of becoming and dying.

Hermann Hesse

Chapter 2

Sources of Uncertainty in Mobile Community Information Systems

This chapter defines the problem statements of this dissertation. Since research on data uncertainty problem has a wide scope, I outline the problem scope with regard to their applications in mobile community information systems. I discuss data uncertainty with various sources ranging from the conventional uncertainty problems in computer science to mobile and web data uncertainty. I define the uncertainty problem to be handled in the dissertation as *Uncertainty 2.0*. Sources of uncertainty 2.0 on mobile and Web 2.0 embrace multimedia semantics and metadata, mobile context, and user interaction. I analyze sources of uncertainty 2.0 from context, semantics and community in a systematic way. The terminologies related to *data uncertainty* and *mobility* are explained to give an overview.

2.1 Brief Description of Data Uncertainty

The real world is uncertain, which leads to many decision making problems. Will it rain tomorrow? Shall I take an umbrella with me? Weather scientists deal with these natural phenomena with scientific measurement and statistics models, which are sources of data uncertainty. At the early phase, the data uncertainty problems were paid attention in Geographic Information Systems (GIS). Here, I give a short overview about general data uncertainty and describe a case study on research domains of cultural heritage and GIS. This section lays a ground for the introduction of *Uncertainty 2.0* as the central research problem for this dissertation.

2.1.1 Defining Data Uncertainty

Uncertainty is a term used in a large range of research fields including philosophy, economics and finance, statistics, philosophy, psychology, sociology, physics, engineering, artificial

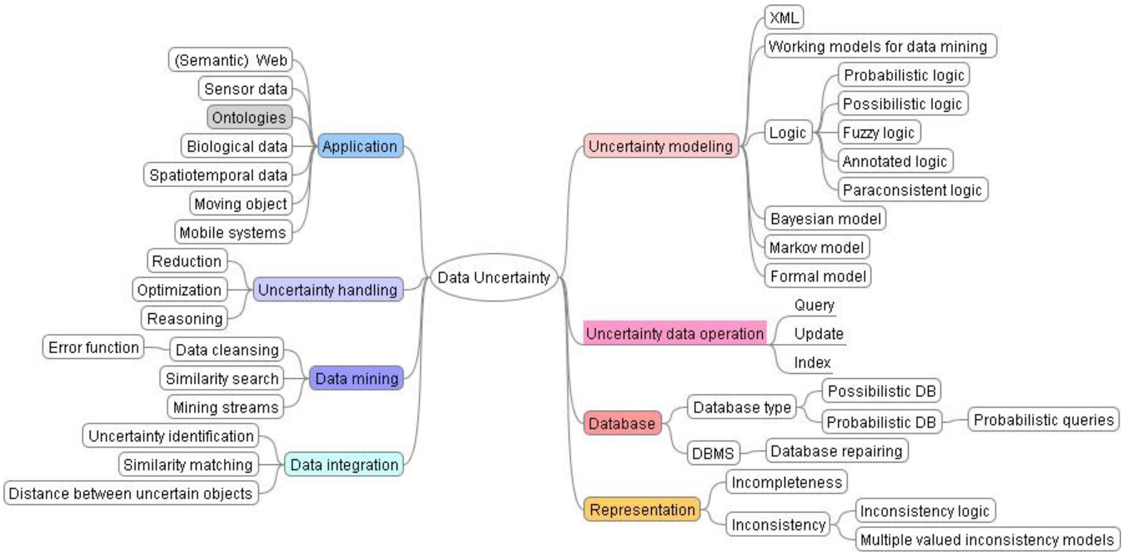

Figure 2.1: Research aspects of data uncertainty

intelligence, information science, and computer science. The data uncertainty problem has been recognized and paid attention in governments, commercial and industrial environments. It occurs to carried-out physical measurements and environment perception, predictions of future events, to support decision making, and to manage information and knowledge. In economics, if outcomes occur with a probability, the decision maker faces uncertainty. It is classified with information, knowledge, and uncertainty with the context of decision-making under risk and uncertainty in microeconomics [AEA10]. In information management, uncertainty has been associated with equivocality or ambiguity [DaLe86]. In artificial intelligence, the uncertainty problem is raised as a big obstacle to attain rational choice in decision-making [Simo81, Halp05].

Data uncertainty has many research aspects as listed in Figure 2.1. In computer science and information technology, data uncertainty has drawn great attention since decades. Data uncertainty research and uncertainty handling are contained in diverse application domains including semantic web, ontologies, context-aware systems, and mobile systems. Data uncertainty problems are acute, if sensor data, biological data, spatiotemporal data [RHE*04], and moving object data [CAAb02, JLOo07] are used. These data sets mainly consist of numbers and texts, and the embedded different types of uncertainty can be analyzed by mathematical methods respectively.

Especially, the database and information system research communities have pointed out that dealing with data uncertainty problems is one of the significant research directions for database technologies [SiZd96, AAB*05]. Measures, models, and reduction methods for data uncertainty problems have been developed in statistics, economics, physics, and geography for many years. Advanced research is undertaken in geographic information systems and computer simulation.

The term *uncertainty* is defined as a measure of the incompleteness of one's knowledge or information about an unknown quantity whose true value could be established if a perfect measuring device were available [CuFr99]. In information systems, Koch et al. [KKMK09] summarize data uncertainty with the following four representations.

- Incorrect or wrong information, e.g. users input data entry with errors.
- Imprecise information, e.g. information measured by devices is not precise due to device limitations.
- Incomplete information, e.g. information is missing in some data records.
- Inconsistent information, e.g. information systems contain information in conflict.

These four aspects answer the question *what is data uncertainty* in most research papers [Lind06, MRHG05]. Let us call it the *4I* (incorrect, imprecise, incomplete, and inconsistent) uncertainty representation and take it as the definition of data uncertainty [KKMK09].

> *Data uncertainty* refers to incorrect information, imprecise information, incomplete information, and inconsistent information (4I).

Many information systems and research areas are highly influenced by the problem of data uncertainty including database management systems, multi-agent systems, peer to peer systems, sensor networks, data stream management systems, reputation systems, context-aware systems, artificial intelligence, self-organizing systems, information retrieval, semantic web, market economics, decision science, and fuzzy systems [KKMK09]. Hence, data uncertainty problems are acute in all data-driven and data-intensive systems.

Data uncertainty representation can be concluded in Figure 2.2 that depicts an uncertainty and resolution classification scheme [FCWa06]. Well defined objects refer to the data models in which the object classes are easily separable from other classes and the individual instances are clearly distinct from other instances of the same class [CFHG06]. The main uncertainty of well defined objects is related to positional, temporal, and attributes errors. Some obvious errors, such as a misspelling of a building name, can be detected and estimated by data mining methods. Hardly detected errors can be analyzed by using probability theory. The uncertainty in poorly defined objects is vagueness and ambiguity. Vagueness arises from the equivocality of spatial and temporal data. For example, it is difficult to identify the spatial extent with unclear data. Ambiguity is further divided into discord and non-specificity. Discord occurs when one object may be placed into two or more different classes under different schemes. Non-specificity arises when an object may not be defined clearly. This data uncertainty representation complies to the aforementioned *4I* representation as well.

Data uncertainty problems can be caused at different phases including data capture, data processing, and data retrieval. During data capture, sensing uncertainty and sampling

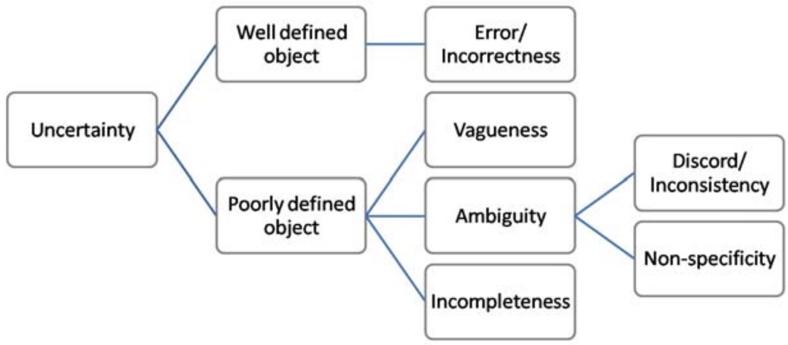

Figure 2.2: Uncertainty and resolution classification scheme [FCWa06]

uncertainty happen frequently. At the data collection phase, imprecise or even wrong data could be generated due to device limitations such as low power and imperfect environment parameters. People who conduct the data capture survey might manipulate the devices in a wrong way or read the false data from the display [KSJ*06a]. But in the existing research work the analysis of uncertainty is focused on the well defined geographic objects. And the procedures of evaluating spatial and temporal data quality are mostly related to the data error and accuracy. At the data processing phase, a false data model could be applied. Some statistical methods are applied onto data for prediction, not for precise calculation. An inappropriate probabilistic density function (PDF) could be specified and used or round functions are applied in some intermediate results, which leads to imprecise final results. At the phase of data result representation, plot resolutions of printers and reporting presentation techniques can spoil data quality as well.

In summary, uncertainty data management aims at adaptation of traditional database management techniques for uncertain data [AgYu09]. In this sense data management refers to data storage, data indexing, and data processing in database management systems. Uncertainty is raised during data acquisition, processing, and reporting. The influence of users who have both positive and negative effects on data is seldom considered. Many existing solutions to reduce data uncertainty are based on fuzzy logic and probabilistic functions. However, additional data processing operations are executed to specify the fuzzy logic or probabilistic functions, which leads to additional data uncertainty as well.

2.1.2 Multimedia Metadata and GIS Uncertainty

The data uncertainty problem in geographic information systems represents the spatiotemporal uncertainty. Real-world spatial or environmental data processing encounters serious uncertainty problems. Since most spatial data is subject to some uncertainty, it affects the reliability of geographic information system applications.

There are a number of research papers that focus on categorization of spatial data uncertainty. One of the earliest conceptual frameworks for geospatial uncertainty was proposed by Sinton [Sint78] with separate error components of *value*, *space*, *time*, *consistency*, and *completeness*. A big problem is about uncertainty in spatial relationships [Vazi00], e.g. uncertainty about whether *Place A* is located in or adjacent to *Place B*. Sources of GIS uncertainty are categorized in three levels in a taxonomy given in [Ales98]:

- Sources of uncertainty cover inherent uncertainty, measurement uncertainty, model uncertainty, data usage uncertainty, as well as processing and transformation uncertainty.
- Forms of uncertainty embrace positional attribute, time, logical consistency and completeness.
- Resulting uncertainty is represented by final product uncertainty.

In [GaEh00] five types of uncertainty are given. They are error/precision in data or value, space error/precision, time error/precision, consistency, and completeness. These uncertainty types are matched against four models of geographic space: field, image, thematic, and object. The common way to classify the data uncertainty uses five data quality categories in the Spatial Data Transfer Standard (SDTS) [SDTS10]: lineage, positional accuracy, attribute accuracy, logical consistency, and completeness. Similarly, temporal data uncertainty can be classified in the same way. The terms *accuracy* and *precision* are distinguished in the relationships to the reality. Accuracy refers to model the relationship between a measurement and the reality, while precision refers to the quality degree of manipulation or reporting of a measurement in arithmetic calculations [Good93].

There are also classifications of data uncertainty according to the uncertainty sources. In [SWLW03] spatial and temporal data uncertainty is classified in detail according to the uncertainty sources in some data mining processes. Besides errors, data uncertainty further includes positional uncertainty, attributes uncertainty, topological uncertainty, inaccuracy, imprecision/inexactitude, inconsistency, incompleteness, repetition, vagueness, noise, emittance, misinterpretation, misclassification, abnormalities, and knowledge uncertainty.

Many GIS metadata standards are applied in the domain of cultural heritage management. GIS technologies have been applied in two fields: retrieving and sorting the documentations about cultural heritage, and monitoring of archaeological sites or findings. Historical documents, maps, research papers, and multimedia files could be classified and captured by their associated cultural objects. The locations of the cultural objects, such as sites and architecture, could be mapped into maps of different scales according to their related spatial information. Therefore, cultural heritage data can be stored, managed, analyzed and displayed efficiently under the spatial reference systems. That facilitates accessing and manipulating data in the information system. However, data problems in spatial reference databases support for GIS have emerged with the increasing demands of data quality [RHE*04]. Inappropriate data models cause data uncertainty problems.

In early GIS, *time* has not been considered as a component of spatial objects. Therefore, many existing information systems of cultural heritage management are supported by only spatial referenced databases. But cultural heritage management is concerned with many research fields such as archeology and history. In these research fields, researchers deal with not only spatial data but also temporal data of cultural heritage respectively. Spatial data associated with cultural heritage objects might vary during different periods. Due to lack of temporal reference, cultural objects cannot be analyzed under temporal conditions.

In addition, cultural heritage data is often stored as a big multimedia repository, where metadata needs to be applied widely. Metadata is data about data. Metadata is tightly associated with different application domains, in order to describe content appropriately. Stvilia et al. [SGT*04] point out that metadata uncertainty is related to context of information use and the relevant information-using communities. Metadata uncertainty is domain specific and caused by the variety of metadata standards in different domains ranging from geography, cultural heritage management, to multimedia. Metadata standards in different domains are discussed in Chapter 3.

Uncertainty of data value is a very normal problem in the databases for cultural heritage. The information system retrieves a large amount of data from various data sources. Meanwhile, the data is represented in all sorts of formats and has different degrees of data quality. It is difficult to find an appropriate answer for certain data values by mining the uncertain cultural data. In addition, the users don't know whether the information they ask for is correct or not. Certainly, they could not always be informed how uncertain the data is.

In conclusion, data uncertainty in cultural heritage management are caused by or derived from these three possible source categories:

- Context uncertainty includes spatial uncertainty of cultural objects and sources to semantics. Spatial uncertain is caused by measurement errors, geometric approximation, and computation errors, due to complexity of the real world. Source uncertainty could be incomplete source information, imprecise representation in data sources, etc.
- Semantics uncertainty is caused by rich semantics of a large amount of multimedia data which is important working resources for cultural heritage management, on the one hand. On the other hand, incomplete cultural data leads to missing semantics.
- Community uncertainty is caused by various users with different knowledge and experience levels. Cultural heritage management amateurs' input and experts' input may have great differences.

The formulation of the data uncertainty problem in this dissertation (cf. Section 2.2) is derived from my brief conclusions on uncertainty sources in the domain of cultural heritage management above.

2.1.3 Case Study

Data in the domain of cultural heritage management consists of a large amount of metadata related to multimedia, GIS, and cultural heritage metadata standards. A case study of uncertainty is surveyed in the Afghan cultural heritage databases [KSJ*06a]. Three main problems of the data in the database have been analyzed according to imprecision of maps, monotony of data, and inconsistency.

Imprecision of maps is resulted by rough usage of image files for spatial data sources. The whole map of Afghanistan consists of 152 image files. Each image presents one degree in latitude or longitude. They range from 29 degree north and 65 degree east to 38 degree north and 74 degree east for the whole country of Afghanistan. Although the number of individual image files is large, it does not stand for the accuracy of the map. The map image cannot be regarded as information provider but as a visual illustration of image files.

In addition, each site or monument is represented as a point with a pair of coordinates, the latitude and longitude. The precision of the geographical coordinates only ranges to the unit of one minute. However, one minute of arc in latitude or longitude equals about 1.8 kilometer[1] in the reality. As a result, the location of a site or a monument is not unique. Many sites have the same latitude and longitude value. For example, I sampled 100 records out of over 800 records in the database table about sites and monuments. Within the 100 monuments or sites, there are 6 pairs and another 2 triples that have the same coordinates.

The problem *monotony of data* stems from the monotony of data resources. If the given information is incorrect, no other resources can be used to correct this wrong information. Information in this database is mainly extracted from written documents. It provides information and rules for the further restoration and conservation of cultural heritage. However, there was a research gap lasting over twenty years, which has limited the progresses in research in this field. For example, all site information including its location, dates, and description is stored in one database table. Each site has at most one piece of description that is taken out of one written document. Till then, the database table comprises around 870 records of site. Among them, about 92.9% of all the records are associated with the data from the book - *Archaeological gazetteer of Afghanistan: Catalogue des sites archéologiques d'Afghanistan* - published in Paris in 1982. The remaining records are focused on four other books. Some other database tables use this source information, too. However, the use range is not much wider than the database table of site. Although the database table of sources is one of the tables that hold the most records, the number of referenced sources occupies fewer than 2%.

Another problem associated with the monotony closely is that there are a great number of records that have many empty attributes, i.e. those records are incomplete. Clearly, this is a consequence of empty input fields, while the information was added into the database. But some records cannot give any useful information, in case that they have only one attribute with a value.

[1] http://www.zodiacal.com/tools/lat_table.php

Inconsistency problems are mostly caused by missing means for data consistency checking. The consistency of the data in the database cannot be checked entirely, because the Microsoft Access database contains only the basic relationships among data in the various tables. Not all data constraints as well as relationships between tables have been established. If the aforementioned example on the limited data source information is considered again, only five records of all sources are shown as referenced in the table of source. In fact, this information is just associated with the table of site. In all the other tables, the information that also references to some certain sources is not presented in the table of source. Such problems result in the incompleteness even the incorrectness of search results straightforwardly.

This case study shows that the representation of uncertain data is imprecise, incorrect, incomplete, and inconsistent.

2.2 Uncertainty 2.0

The data uncertainty problem has a wide scope and its handling process is complex. The aforementioned *4I* uncertainty representations (cf. Section 2.1.1) define how data uncertainty is observed in the literature, while application domains are not described. Thus, I describe the new concept *Uncertainty 2.0* according to the context, semantics, and community aspects in mobile community information systems.

2.2.1 Definition of Uncertainty 2.0

Uncertainty 2.0 arises with the emergence of many *2.0* technologies ranging from Web 2.0 [Orei05], e-Learning 2.0 [Down07, Alex06], to Enterprise 2.0 [MFKe05]. Web 2.0 multimedia is characterized by a huge amount of user-generated content, various multimedia operations, and domain specific metadata. Mobile multimedia has the additional characteristic of device diversity. Multimedia data is generated more easily and quickly. However, data uncertainty is not reduced, but is even increased, when media becomes more and more abundant. Sources of uncertainty 2.0 come from users' activities on user-generated content. It cannot be observed independently from but continuously with the present uncertainty.

In addition, mobile applications process a large amount of context information. Web 2.0 and mobile phones raise new challenges to handle uncertainty. At the same time, new institutional models for data quality are missing or emerge slowly [Shir10]. The data uncertainty problem is not only limited in the data level, but has many influences given by metadata [SGT*04], semantics, context, user communities, etc. Thus, uncertainty 2.0 can be analyzed on different levels.

Figure 2.3 depicts the three important aspects to formulate uncertainty 2.0: context uncertainty, semantics uncertainty, and community uncertainty. Each aspect is explained in detail from Section 2.2.2 to 2.2.4. Both Web 2.0 multimedia and mobile multimedia are treated

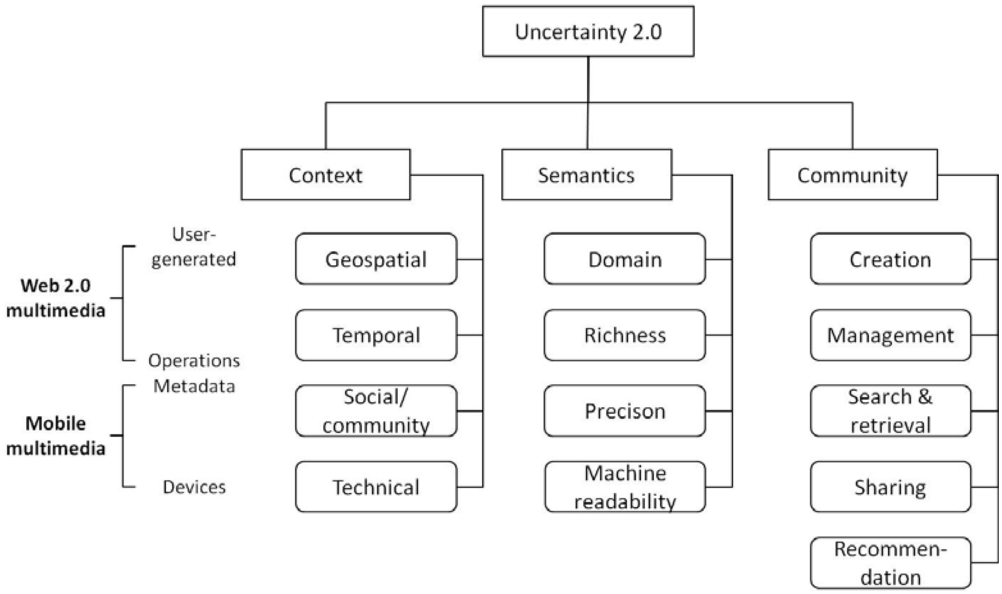

Figure 2.3: Formulation of Uncertainty 2.0

with (community) operations and (semantic/context) metadata. Web 2.0 multimedia management focuses on massive user-generated data, while mobile multimedia on device-based adaptation.

> *Uncertainty 2.0* refers to data uncertainty problems with focus on multimedia semantics, context, and influences of user communities in conceptualizing and realizing mobile community information systems.

Data uncertainty problems may occur in these three aspects respectively or in a combination, as depicted in Figure 2.4. Use of the similar tags of "semantic-web" and "semanticweb" should not be users' intention. This kind of semantics uncertainty is caused by mistake. Inconsistency problems are reflected at using different terms as individual tags and in the superset, the tag bundles. In addition, platform-targeted tags are treated in the same way as the other tags, e.g. "@twitter". This action could address media to wrong communities and leads to community uncertainty. Other uncertainty includes missing or wrong temporal tag information for web links, which is related to context uncertainty. For example, a web page of an annual conference could be hosted with the same URL from year to year. Thus the tags with year information could be false context information.

2.2.2 Context Uncertainty

Context uncertainty refers to poor quality of contextual data acquired directly from the environment, e.g. location information sensed by GPS devices, temporal information,

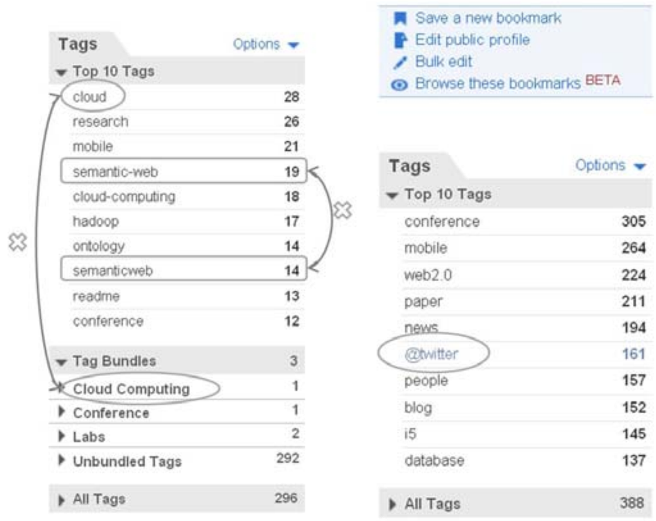

Figure 2.4: Uncertainty in social bookmarking site *Delicious*

social/community context information, as well as device-related technical information. Social and community context refers to relationships between users [KSCa06a]. And uncertainty could be increased by changes of other users' interest within a community.

The term *context* itself has some uncertainty due to various definitions in different disciplines. In information systems Dey [Dey01] gives a widely-accepted definition as follows:

> *Context* is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.

This definition relies in uncertain characteristics, because it covers a large number of entities with their situational information, which can be location, time, and so on. According to Dey's definition, multimedia data is one of the entities with context information.

Consequently, it is difficult to avoid the problems with data uncertainty especially in context-aware systems. Inconsistency occurs between models and the real world, as well as among different local environment models. In [HeIn04] four main factors are stated which lead to that context inconsistency:

- *Unknown*: when no information about the property is available;
- *Ambiguous*: when several different reports about the property are available (for example, when two distinct location readings for a given person are supplied by separate positioning devices);

- *Imprecise*: when the reported state is a correct yet inexact approximation of the true state (for example, when a person's location is known to be within a limited region, but the position within this region cannot be pinpointed to the required application-determined degree of precision);
- *Erroneous*: when there is a mismatch between the actual and reported states of the property.

Correspondingly, Quality of Context (QoC) or Quality of Information (QoI) is often discussed. Quality of contextual information depends greatly on the change of context sources, by which context is provided [LSD*02]. In uncertainty 2.0, context sources are categorized in geospatial, temporal, social/community, and technical. They are well applicable for mobile multimedia.

2.2.3 Semantics Uncertainty

Semantics is specified as degree of both machine-readability and human-understandability in the Semantic Web [Bern98]. The differences between the multimedia semantic interpretations of computer systems and of humans have been paid attention firstly in [SaJa98, Delb99]. Semantic gaps exist between situated meanings and perceptual clues in databases of images [SaJa98], and describes the inability to get semantics out of multimedia low level technical features in multimedia retrieval as well [Delb99]. Semantics uncertainty refers to a range of different meanings embedded in multimedia content and it is described by four aspects: domain, richness, precision, and machine readability. An object may have different semantics in different domains. Richness implies the degree of expressiveness which could be contradictory or in line with precision. Machine readability is attained by standardization and metadata standards.

Domains make semantics vary. Semantics of the same term may indicate different concepts in different domains. The semantics of "creator" of the same photo of a painting in the communities of painters and photographers may refer to different information. It could be the person who has painted this painting, or the person who has shot a picture of this painting. In addition, different languages can also be considered as domains.

Richness and precision are considered as a contrary value pair. Richness refers to expressive richness and is highly related to uncertainty degree. Precision refers to accurate use of multimedia and operations on multimedia. The flexibility is lost and richness decreases, if the precision scale is enhanced. Languages are full of expressive richness. Research in linguistic shows that language has a scalar of certainty. French has a higher certainty as a diplomatic language, while Chinese is the most uncertain language. Multimedia has high richness as well and may convey different information to different multimedia consumers, which leads to many data uncertainty problems. In addition, users tend to add various tags to photos instead of putting them into different folders in the current digital photo management process. This *n-m* relationship makes a set of rich tag indices for photos in a miscellaneous way, which increases uncertainty. Thus, a compromise for richness enhancement could be made between uncertainty and precision for Web 2.0 and mobile multimedia operations.

Machine readability requires appropriate transformation processes with regard to precision and consistency, while these aspects above have focused on users' readability. Metadata standards are able to play this role. Metadata uncertainty focuses on the underlying metadata standards, the selection of appropriate metadata standards, and the usage of certain metadata elements.

As an example to semantics uncertainty, more data uncertainty could be caused if users add more information to existing information. Adding more information to images for semantic richness leads to the overabundance of information. Before the "tagging" era, sometimes people do not know what categories they should put their data. That a book is placed on one shelf in libraries shows the stickiness of physical objects and precision of information. Digital information with folder management can be freed from this way. Digital copies have had this freedom rather than physical objects. But they are still stored in file systems in hard disks. Weinberger [Wein07] stresses the effectiveness of miscellaneous sorting, ordering, and clustering of digital photos. On the contrary, people add tags, which leads to the tag ambiguity problem. The more tags that are in use, the more access information can be got and the more errors may occur. Additional errors related to tags might be forgetting to add one tag or typing errors.

2.2.4 Community Uncertainty

Community uncertainty observes data uncertainty problems related to users and user communities. Uncertainty occurs when users' operations are diverse and uncertain. Uncertainty also occurs when context is switched between different user communities. For example, Shacklett [Shac01] showed that 28% of e-commerce web transactions are resulting in user errors and subsequent frustration. 6% of the visitors leave the website because of errors stating that they did not want to use it anymore. One of the biggest problems is accuracy, as popular websites only provide basic annotation support such as keyword tagging [Smit07] or simple text descriptions.

A huge number of social network sites are launched where users play a more and more important role. Even in GIS research area, Goodchild [Good08] has raised the questions about accuracy assessment of the vast quantities of geospatial data contributed by individual web users. Uncertainty 2.0 is associated with user communities. Drucker [Druc99] has identified the big gap between data producers and data consumers. The producers of data cannot possibly know what data the consumer communities need to make data become useful information. This kind of understanding bias represents community uncertainty.

Community uncertainty is related to multimedia operations on Web 2.0 and mobile applications (cf. Figure 2.3). Web 2.0 operations can be considered as various kinds of tagging activities, e.g. to give keywords as a simple tagging activity. Different web sites have different formats for tagging, which leads to uncertainty. Operations such as rating resources or recommending resources to communities, and a set of other operations also lead to data uncertainty as well. Users choose some arbitrary social actions between *like* or *share*. Neglected actions can lead to abuse of social data spheres ranging from private, business/community, to public spheres. People tag and visit web pages, which is sometimes a distraction from other web pages by accident. False web link clicking or false tagging could happen.

In short, uncertainty is caused by large-scale applications on the Web 2.0 and conflicts between data collection mechanism [AdRe07]. Either the tipping point [Glad07b] or the long tail phenomenon [Ande06] shows the vast impacts by user communities. Research questions could be social aspect, users, context, multimedia, and evolving user communities [Ley09]. Users' uncertain information is a sub class of erroneous cognition or erroneous events from users. Thus, user factor is a crucial trigger for the knowledge transformation chain and can be used to improve the data quality [Klam00].

2.3 Uncertainty Impacts on Mobile Information Systems

Web and mobile applications merge nowadays [RHBl07] and uncertainty 2.0 is embodied in mobile information systems. A medium is social, ubiquitous, and cheap, according to the usage ways including creation, distribution, and consumption [Shir10]. Advances in mobile and smartphone technologies make media per se more social and more ubiquitous via mobile multimedia creation and sharing.

2.3.1 A Mobile Uncertainty Scenario

With the development of mobile technologies, mobile applications facilitate mobile users' mobility in various application domains such as technology enhanced learning and cultural heritage management. Mobility can be supported from physical, technology, conceptual, social, interactive, and temporal aspects [KaSo02].

At the same time, Web 2.0 has been reaching out to mobile handheld devices. Data uncertainty problems need be identified and handled in terms of the both emerging application domains, namely mobile and Web 2.0 community information systems. Mobile applications covers daily life, facilities, and professional communities. In detail, the support ranges from mobile entertainment, taking and sharing pictures, push SMS/MMS, mobile health care, mobile shopping, mobile games, mobile tour guide, professional cultural heritage management, business administration, technology enhanced learning, to disaster victim identification.

In order to illustrate mobile multimedia management, the multimedia information sharing is addressed in sport events which often involve much multimedia semantics and context

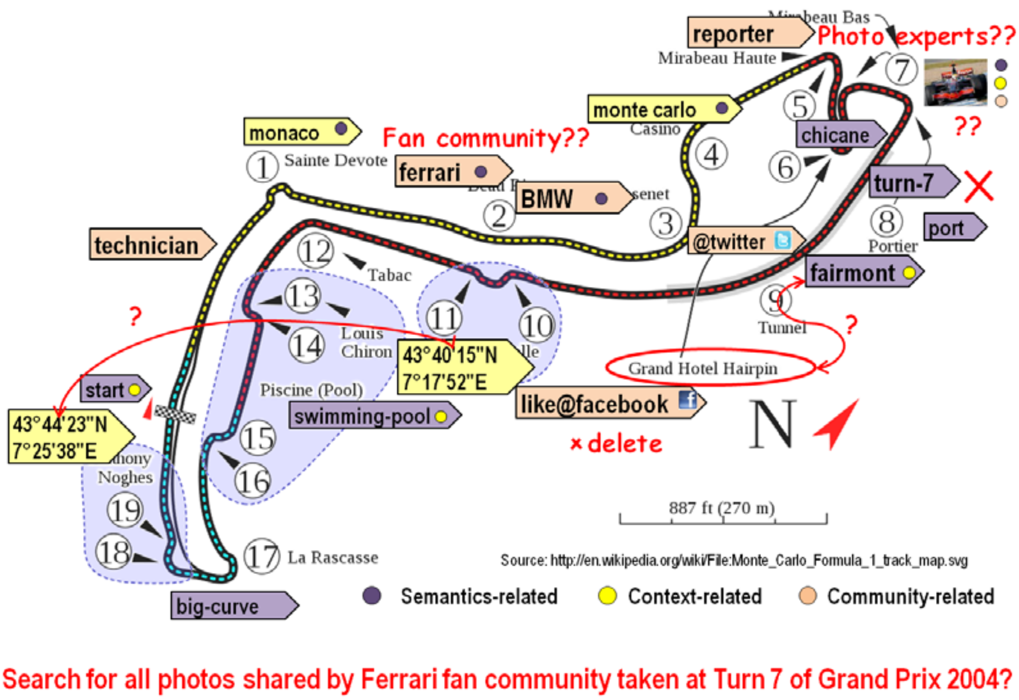

Figure 2.5: A sketch of uncertainty 2.0 for mobile multimedia creation and sharing during watching Formula 1 race

information. The scenario-based approach is well employed to tackle users' in-depth requirements on information systems [HHJP99]. Figure 2.5 depicts the Formula 1 race as a scenario instance.

If people go to some Formula 1 races like Grand Prix, they search for multimedia about drivers before the race. During the race, they record some videos or take photos to capture some exciting moments. The audience wants to get and to share as much information as possible. They take photos and videos, tag the multimedia artifacts, exchange SMS messages, and share the status report in social network sites, e.g. Facebook or Twitter via smartphones. Their location information is recorded without being noticed. Along with a large amount of multimedia artifacts, much annotation information is generated as well. Each multimedia artifact may have one or more tags as depicted in Figure 2.5. Those tags can be grouped into different categories: semantics-related, context-related, and community-related. However, some mistakes may happen with the tags, e.g. false GPS coordinates, use of other terms for the identical object, and false user-generated tags.

The audience may address queries such as "search for all photos shared by Ferrari fans taken at Turn 7 of Grand Prix 2004", "search for the 10 best photos of the Ferrari team at Turn 7 in the last 3 laps", "search for multimedia files at the starting time of the Formula 1 in which Team Brawn GP has won in the recent race", or "search for videos of the Grand Prix in this city last time". The *last 3 laps* are related to the current time context then, while *Turn*

7 is incomplete without any race information. If this query is answered by other people, a lot of knowledge is needed such as current time, current location, current sport event, user community information, and users' feedback on multimedia. Start time, pit stop, or the temporal interval sum of certain laps of certain race teams need a mapping between semantic information and context information respectively.

Furthermore, uncertainty could be raised, because the race has a wide location coverage and certain time spans. The audience could be fans to a certain race club and could also be interested in different race teams. The audience could be technicians or journalists to monitor or report this sport event. Such sub audience groups build up various communities. Individual users also use various kinds of mobile devices with different capacities ranging from different display sizes, with integrated camera or without, to different computing and storage capacities. Most important, the communities are sitting or standing at places distributed over the whole race lap. The audience is able to create multimedia with totally different viewpoints and has demands to share photos or videos with one another. They might also be interested in sharing multimedia files with their friends who just watch the race in TV. After the race, all created multimedia files might be looked through again to share the experience within communities.

In this aforementioned scenario instance, mobile users generate multimedia semantic and context information, while context information is recorded by integrated functionality of mobile devices and semantic information can be automatically created to reduce users' data processing workload. Uncertainty can be resulted from each stage of information processing including:

- Measure or perception errors of mobile devices, e.g. imprecise or even false GPS information about audience tribune location (context uncertainty);
- Input of false semantic information, e.g. users input false lap information by mistake (semantics uncertainty);
- Imprecise representation of multimedia annotation (semantics uncertainty);
- Mistakes caused during automatic metadata extraction from context information, e.g. GPS coordinates maps to a false curve information (semantics uncertainty);
- Users annotate multimedia with false information intentionally, e.g. there exist Wikipedia vandalism users (semantics and community uncertainty);
- Users take false actions to share a multimedia artifact (community uncertainty); and
- Different user communities use different vocabulary sets and have different interpretations on the identical multimedia artifacts (community uncertainty).

2.3.2 Sources of Mobile Data Uncertainty

Due to various complex context information, mobile environments are the big sources to generate uncertainty. Mobile handheld devices are a kind of easy-to-use media creation and consumption devices, through embedded cameras and GPS receivers. Already on the Web, people do not feel certain and trust information which can be easily accessible in the world's hugest information database. Context information is massively generated or collected by mobile devices. It is more challenging to deliver preciser information to mobile device users.

Mobile phones can be used to collect a vast amount of empirical data for a ubiquitous data capture [RSB*09]. This data capture content includes images, audios, videos, motions, profiles, proximities, and locations. The capture process can be manual (pull) or automatic (push), context-independent or context-aware. Context includes location, proximity, activity, and social context. Context also refers to users' context, while mobile multimedia content has its context, too.

The metadata amount also increases correspondingly, which is partly generated by certain context information from GPS or a clock and is partly annotated by users. Some users might annotate one multimedia artifact with event information, while some users annotate the same content with temporal information. Some multimedia artifacts are not annotated at all. All this user-generated metadata may lead to missing information or uncertainty problems.

Context awareness is crucial in mobile application environments. Context information is collected as the first step, and then processed. Aiming to enhance context awareness, mobile systems must produce reliable information, though mobile data is often uncertain, rapidly changing, and partially true data from multiple heterogeneous sources. Mobile devices equipped with low-cost sensors are able to detect some aspects of context. However, extracting relevant context information by fusing data from several sensors proves challenging because noise, faulty connections, drift, miscalibration, wear and tear, humidity, and other factors degrade data acquisition [KMK*03]. At each stage of data processing, uncertainty could arise when wrong data is collected by sensors as well as inconsistent data is integrated [RACa04]. Fault tolerance and speed are identified as the most critical aspects for general multimedia applications, because both audiovisual media and metadata including control information are processed simultaneously [StNa04b]. Hence, the context uncertainty problems are considered as an important aspect for mobile multimedia application development.

2.4 Summary

Besides the "conventional" uncertainty problems which have been handled in computer science since decades, I focus on the emerging uncertainty 2.0 problems. Uncertainty 2.0 deals with context uncertainty, semantics uncertainty, and community uncertainty in a

Categories	Uncertainty	Uncertainty 2.0	U 2.0: mobile uncertainty
Media	Text, number	Multimedia	Multimedia
Sources	Media	Users, media	Mobile users, media
Features	Metadata, context, and semantics separately	A combination of metadata, context, semantics, and community	Focus on context
Typical problems	Monotony, inconsistency	Richness, precision, variety	Mobility
Information processing	Reduce	Reduce and add	Reduce and add

Table 2.1: A comparison of data uncertainty

combined way. Mobile aspects have been paid additional attention in Section 2.3. Thus, mobile uncertainty is compared together with uncertainty 2.0 and uncertainty in Table 2.1. The user factor is crucial in uncertainty 2.0 and mobile uncertainty, in that user-influenced information processes may lead to additional uncertainty issues.

Uncertainty reasoning based on context reasoning is enabled both by metadata-based multimedia adaptation and context-aware multimedia adaptation. Metadata creation is a process of tagging involving three dimensions: tags or multimedia metadata, resources or multimedia content, and users [Smit07]. Tagging within community of practice as a kind of mutual engagement by users can reduce uncertain context information. Furthermore, mobile devices enable situated immediate social context and social interaction, rather than asynchronous communication via desktop computer to find out proximate users [EaPe05].

In my dissertation, uncertainty is treated in connection to rich semantics, many kinds of context information, and high user interaction in communities. Uncertainty within mobile information systems is focused additionally. Data uncertainty problems occurring in information acquisition and extraction are related to finding and annotating information in unstructured text. Moreover, it is necessary to handle and manage data from multiple sources, while inconsistency occurs. Among them, one of the big sources is "human input". Users generate a vast amount of data and metadata with semantics. Thus, handling uncertainty 2.0 with focus on the aspects of scontext, semantics, and communities are crucial, besides the theoretical research in probabilistic data management and fuzzy logic.

By 2047 ... all information about physical objects, including humans, buildings, processes and organizations, will be online. This is both desirable and inevitable.

Gordon Bell and Jim Gray

Chapter 3

State of the Art

Multimedia semantics and context, annotation and digital storytelling provide potential approaches to handling the data uncertainty problems. The state of the art is related to these aspects together with information management, Web 2.0, social software, mobile technologies, and uncertainty issues.

3.1 Information Management

The concept of information processing and information management is the basis for problem identification of uncertainty 2.0 in Chapter 2. It provides a useful framework to understand and design community information systems. In this section, several important theories about information management are introduced. Among them, I focus on the concept of community of practice [Weng98], which distinguishes community information systems from general information systems. Related uncertainty issues are discussed as well.

3.1.1 Information Management Theories

The underlying theories are ground stones for data uncertainty management in community information systems. They contribute greatly to the definition and formulation of the *uncertainty 2.0* problem. I do not focus on concepts of information management in economics and cognitive science, in which information management is one of the main goals and tasks in organizations [MaSi58]. Two theoretical aspects are focused. First, the features of information including information richness tell us what matters for information. Second, information operations give us a guide to uncertainty handling for various purposes.

Daft and Lengel [DaLe86](pp. 560) define *information richness* as follows:

> *Information richness* is defined as the ability of information to change understanding within a time interval. Communication transactions that can overcome

> different frames of reference or clarify ambiguous issues to change understanding in a timely manner are considered rich. Communications that require a long time to enable understanding or that cannot overcome different perspectives are lower in richness.

This definition is also applicable for communities of practice. Information richness corresponds to communication learning capacity, which depends on whether media is personal or impersonal [DaLe86]. Thus, community of practice (CoP) enhances information richness appropriately, while different users in the CoP can be involved. A rich representation uses a wide variety of symbolic languages, such as graphics, voice inflections, and body gestures to convey information. A key characteristic of a presentation medium is its level of richness [LiBe00].

Thus, information richness is related to information representation. In knowledge management, a ground stone for organizational knowledge creation and management is the SECI model by Nonaka and Takeuchi [NoTa95]. The term *SECI* is the initials of their proposed four information operations: socialization, externalization, internalization, and combination. With these four knowledge operations, tacit and explicit knowledge (defined by Polanyi [Pola85]) can be transformed into each other flexibly.

A media-specific theory helps us understand digital media support for discourses in the cultural sciences, e.g. the ATLAS media theory [Jaeg02, Span07, Klam10]. The "*Theory of Transcriptivity*" [JaSt02] describes a medial practice in creating and further developing of a cultural semantics by symbolic means. Thus, transcriptivity describes the underlying basic relation between knowledge organization and communication in non-technical disciplines. It is based on the following three media operations [JaSt02, Jaeg02, SKJa02, FoSc04]:

- *Transcription* is a media dependent operation to enhance the readability of media collections.
- *Localization* means an operation to transfer global media into local practices. It consists of two distinguishing forms: formalized localization within information systems (in digital community media) and practiced localization (in communities of practice) among humans.
- (*Re-) addressing* describes an operation that stabilizes and optimizes the accessibility in global communication.

These media specific operations can be synthesized with learning processes of communities of practice. The result is a media centric re-formulation of the previously introduced media operations on knowledge creation and social learning processes adopted from Nonaka and Takeuchi [NoTa95] and Wenger [Weng98]. Figure 3.1 brings together both approaches in media centric theory of learning in communities of practice. It combines the two types of knowledge: tacit and explicit [Pola85, NoTa95]. The derived knowledge creation and

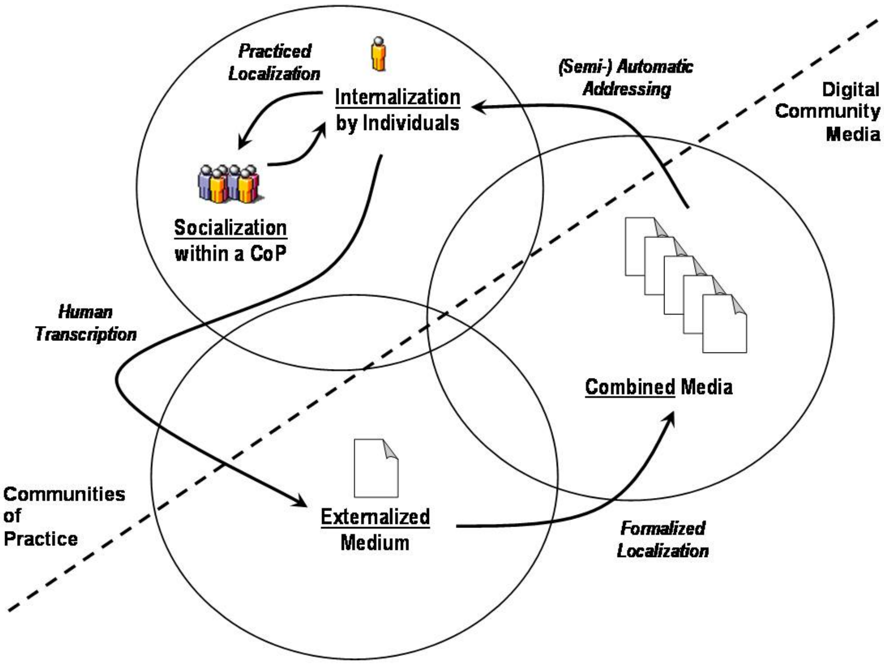

Figure 3.1: The ATLAS media theory of learning in communities of practice [SKJa02]

learning processes in the media theory include its media specific operations: transcription, formalized as well as practiced localization, and (re-) addressing.

In the upper part of Figure 3.1, actions performed by humans are focused on. Starting with an individual who has internalized some media-specific knowledge, there are two ways to communicate with others. On the one hand, there is an option to present this information to others by human-human interaction in practiced localization, which allows the content's socialization within the communities of practice and vice versa which is equivalent to the development of a shared history. On the other hand, individuals may also perform a human transcription of their knowledge by generating new medial artifacts. This operation switches the focus to the lower part where digital community media is processed. The externalized artifacts of an individual are further processed by the information system through the formalized localization of the medial artifacts. In contrast to its high-level transcription by an individual, here, a technical computer supported recombination of medial artifacts takes place. As a result, the set of medial artifacts from various data types are combined within the information system. The final (semi-) automatic addressing closing the circle is the context depending presentation of the medial artifacts or a cross-medial concatenation. From then on, the process might be repeated infinitely oscillating between tacit and explicit knowledge on the epistemological axis and between individuals and the communities of practice on the ontological axis.

Although the media theory and media-centric approaches [Jaeg02, Span07, Klam10] enhance multimedia semantics, adaptability, and interoperability, it is not adequate to handle data uncertainty in mobile Web 2.0 applications.

Moreover, knowledge is about comprehension of information, which cannot be measured. Thus, additional support or tools are required to make information pass to knowledge. Brown and Duguid [BrDu00] define it as follows:

> *Knowledge management* is the use of technology to make information *relevant* and *accessible* wherever that information may reside. To do this effectively requires the appropriate application of the appropriate technology for the appropriate situation.

The word *relevant* is about the media and information, while *accessible* is targeted to user communities. Information is self-contained. People can collect, organize, pass around, store, search, also lose it. Knowledge is hard to collect and hard to transfer. Knowledge is to be digested instead of transferred [BrDu00].

3.1.2 Community of Practice

The term *community* means the quality of holding something in common, as in community of interests or community of goods. It comprises a sense of common identity and characteristics [Duri99]. Similarly, community of practice (CoP) is additionally derived from the learning theories. Wenger defines *Communities of Practice* as groups of people who share a concern or a passion for something they do and who interact regularly to learn how to do it better [Weng98]. He stresses that a community is a *community of practice* only if it has the following three dimensions:

- *Mutual engagement* defines the community of practice with a certain shared domain for the common engagement. It enables engagement of diverse members of the community who possess mutual relationships among themselves.
- *Joint enterprise* suggests that it be important to set the game regulations in the community. The members of the community of practice should cooperate with each other, help each other, and share information.
- *A shared repertoire* is provided to the community members. The practice is an important factor in the CoP and its results in form of resources, experiences, multimedia artifacts, stories, and tools etc. can be shared among the community members.

The concept of community of practice is useful in the context of organizational information management [Weng98]. This concept has been applied to a number of various settings for research, business management, and in the social sciences. More and more corporations, institutions, and organizations have been developing projects based on this concept aiming at community outreach and engagement [BrDu00]. For example, community of practice has been pioneered by the Institute for Research on Learning, a spin-off of the Xerox Corporation. The institute pursues a cross-disciplinary approach to learning research, involving cognitive scientists, organizational anthropologists, and traditional educators[1]. The application patterns to implement the CoP concept are diverse. The Bulletin Board Systems (BBSs) are early forms. Many other representation forms include Computer Supported Cooperative Work (CSCW), community labs, groups on social networking sites, and so on.

Related to the concept of CoP, we know that processes are important to make organization work. Nevertheless, people's practices make processes work. In this sense, *practice* plays a crucial role in CoP. Both process-based and practice-based aspects of organizations are usually considered. However, knowledge comes from practices of colleagues rather than from processes [BrDu00]. Thus, practices should be focused on, which aim at accomplishment of processes. Three operations are proposed in [BrDu00]:

- *Collaboration* includes collaborative problem solving and collective solution sharing. Difficulties in this process is delay between identifying the problem and providing the part to fix it.
- *Narration* is an approach to storytelling about problems and solutions, about disasters and triumphs. It could serve a number of overlapping purposes. Narration is started with unsolved problems, and further developed via a coherent account of the problem solution in an individual or collective way.
- *Improvisation* is opposite to routinization. Improvisation can free the model from routines and processes.

According to this definition, multimedia annotation and storytelling are suitable and efficient practices in communities. In addition, appropriate information processing models are needed. At the same time, it is crucial to analyze how the community of practices is built up. Who are the community members? Which roles do they play? Activities and requirements of different members should be considered. In this sense, long tail community of practice is important as well. For the popular culture and top, there is a ranking mode.

For example, learning communities are cases for CoP. Learning communities process information in six stages within a life cycle: proposal, refinement, organization, pursuit, wrap-up, and publication [LeCe02]. I identify several crucial aspects for the success of learning communities:

- Involvement of outside expertise and experts;

[1] http://www.infed.org/biblio/communities_of_practice.htm

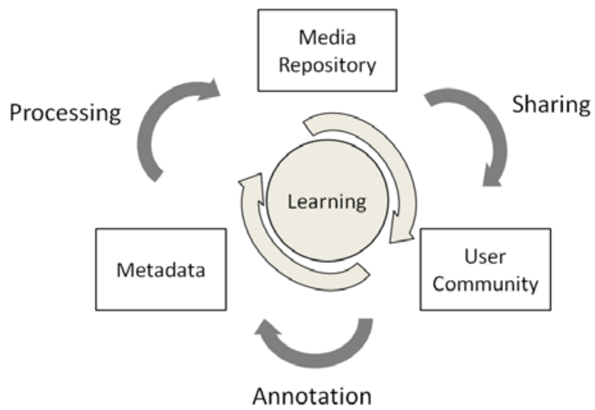

Figure 3.2: Learning as a central goal in CoPs

- High interaction among community members and platforms;
- Use of various multimedia artifacts or operations;
- Frequent message exchange in different phases.

Moreover, how learning communities process information is depicted in Figure 3.2. The community uses media repository and metadata as a sharing repertoire. Community members are mutually engaged in practices like learning resource annotation, sharing, and processing. These practices measure and realize the learning process with learning as a central goal. The practices are embodied in multimedia operations, e.g. annotation and storytelling. Generally speaking, information processing is one of the most important aspects for organization design and community information system design.

In summary, the concept of community of practice is applied to information systems, in order to stress the social aspects of information. Brown and Duguid [BrDu00] argue that it is not adequate for technology design to only aim at an idealized image of individuals and information. Instead, the solution lies in socializing technologies such as telephone, e-mail, and blogs. Community of practice is a concept for realization of *community awareness* [KSCa06b], *community role models*, and *community behaviors*.

3.1.3 Uncertainty Issues

In the context of organizational information processing or in CoP, *uncertainty* refers to absence of answers to explicit questions. Uncertainty requires obtaining of objective information to answer specific questions. On the other hand, *equivocality* stems from ambiguity with overfilled messy information and requires explicit problem definition through conflict resolution [DaLe86].

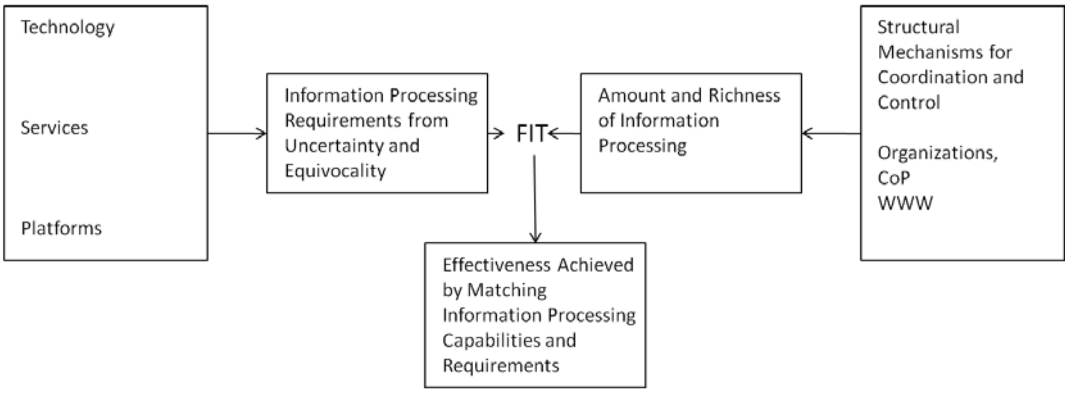

Figure 3.3: Summary model of information processing and organization design (extended from [DaLe86])

Media transfer processes or approaches have different impacts on uncertainty issue. Daft and Lengel [DaLe86] stated that face-to-face media transfer has more uncertainty than written media. The design of organizations enables additional data processing to reduce uncertainty [TuNa78].

Uncertainty is seen as a hazardous factor for organizational survival among the three principal dimensions of organizational environments: munificence, dynamism, and complexity. Technological uncertainty is raised due to unclarity of what kind of technologies would become a standard [AnTu01].

Figure 3.3 shows that organizations or communities of practices can be designed through mechanisms to manage equivocality and uncertainty [DaLe86]. Seven information processing means are discussed for organizational information management: group meetings, integrators, direct contact, planning, special reports, formal information systems, and rules and regulations. Among them, *planning* is specified as a dynamic process both for equivocality reduction and data sharing. The higher the degree of data sharing, the less the data uncertainty degree is.

Information processing tasks increase or decrease depending on the complexity or variety of the organization's tasks [DaLe86]. Solutions to reduce uncertainty include obtaining additional data and seeking answers to explicit questions. It is questionable whether additional data helps reduce data uncertainty of the existing data set.

3.2 Web 2.0

Since around 2000 Web 2.0 has emerged and had common aspects with the concept of community of practice. The important Web 2.0 concepts and technologies are discussed in this section.

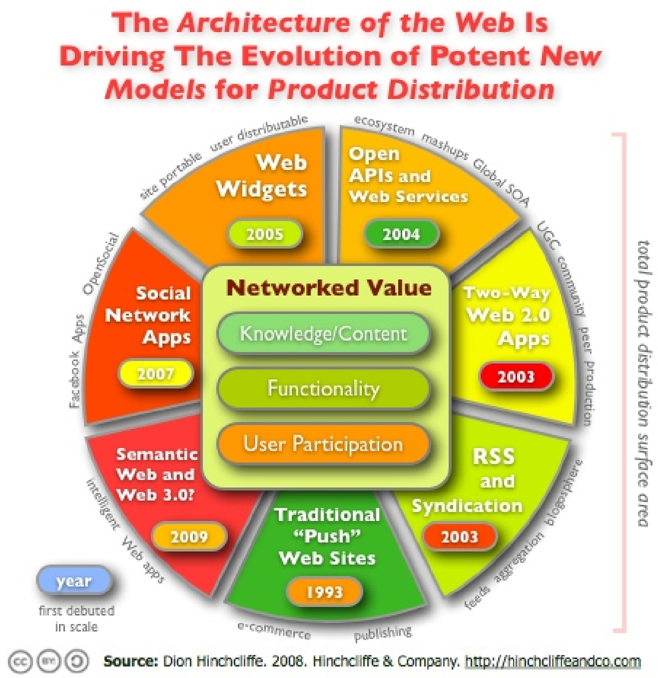

Figure 3.4: Evolutions of web product distribution models [Hinc08]

3.2.1 Web 2.0 Business Model

Web 2.0 business models pertain to information processing models on Web 2.0 data. Tagging is one of the models for heuristic information processing, while semantic web aims at systematic information processing. Hinchcliffe [Hinc08] depicts a complete diagram to summarize the development of Web 2.0 in the field of product distribution (see Figure 3.4).

The Internet in general and especially the Web are assumed to be one of the really big media revolutions. After only roughly 15 years of existence, the Web is replaced by the Web 2.0, a term coined by Tim O'Reilly. Projects like Wikipedia let users become knowledge prosumers (consumer and producer in parallel) of wikis, replacing old-fashioned content management systems in organizations. Interoperability between content and services is realized by syndications tools. In order to highlight the differences between the new and the old Web paradigms, we introduce the core of Web 2.0 knowledge management presented in O'Reilly's seminal article [Orei05].

First, user participation is replacing publishing. Although Web 2.0 is featured with "Data are the new Intel Inside" [Orei05], users and communities play a more important role. They participate in media creation and sharing processes. Simple web publishing is not the final goal any more. Second, syndication frees information stickiness. Web 2.0 sites support Really Simple Syndication (RSS) instead of placing a button labeled with "set this page to your home page". Third, Wikis are applied instead of content management. This openness is supported through wide employment of open standards. Finally, folksonomies are replacing taxonomies. Web 2.0 often uses tagging technologies to categorize multimedia content. Even if users misuse tagging and create false or misleading tags for multimedia content, content-based retrieval techniques can be used to validate retrieval results based on simple keyword search.

Different prevalent social network sites (SNS) aim at different communities as Dasqupta's [DaDa09] classify social networks into mixed networks, e.g. Facebook, specialist networks, e.g. LinkedIn, and retail networks, e.g. Wal-Mart and so on.

In Web 2.0 I conclude the following interesting aspects based on several observations:

- Social network sites provide their social network services as plug-in's which can be used at different Web sites. This is, de facto, a success model of cloud services. Interoperability is enhanced.
- Standardization is crucial and is the trend in spite of different platforms. Different platforms aim to keep their users and compete for new users on the one hand. On the other hand, they create a bridge to connect to other platforms.
- New vocabulary is coined as a side product, especially some verbs including *google*, *blog*, and *twitter*, etc.

3.2.2 Semantic Web

Since Tim Berners-Lee proposed *Semantic Web* in 1997, the goal that applications are able to understand data has not been changed. Questions are addressed in Semantic Web road map [Bern98]. What is Semantic Web? What is not Semantic Web? What can Semantic Web do? Will Semantic Web change our life?

Tim Berners-Lee [Bern98] points out that Semantic Web is a web of data, in some ways like a global database; ... a universal Web of semantic assertions; ... an extension of the current Web in which information is given well-defined meaning, better enabling computers and people to work in cooperation.

> The Web was designed as an information space, with the goal that it should be useful not only for human-human communication, but also that machines would be able to participate and help. - Tim Berners-Lee

In recent years, Tim Berners-Lee et al. [BHH*06] have also further proposed the discipline Web Science including the research topic Semantic Web. Web science aims to identify the essential aspects of identification, interaction, and representation that make the Web work, and to allow the implementation of systems that can support or promote desirable behavior.

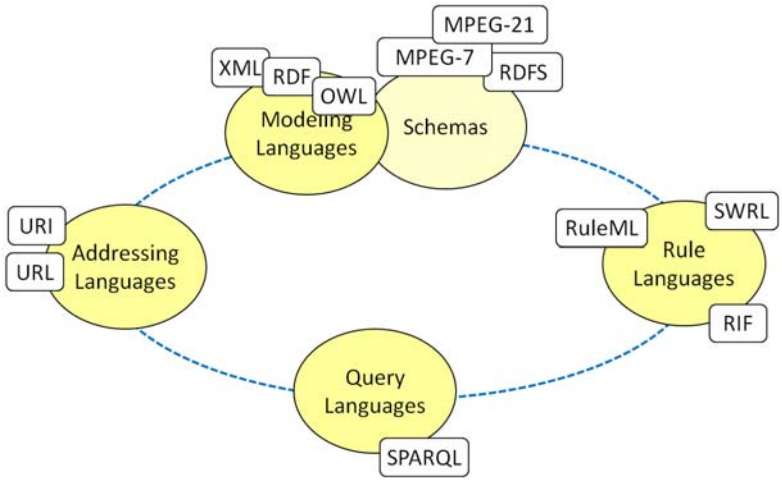

Figure 3.5: Semantic Web languages

Semantic Web provides a better way to organize unstructured information on the Web. For example, search on the Web is often related to multiple web sources. With the Semantic Web technologies, the multiple web sources are labeled with semantic information under a predefined taxonomy. Thus, the suitable web sources can be used for query processing [TCLi09]. Predefined taxonomy and ontology are keys to the Semantic Web technologies.

Data is processed in four steps on Semantic Web. Step 1 focuses on text documents and database records. Data is application based, while semantics is behind applications, e.g. product catalog of Amazon. At Step 2 XML (Extended Markup Language) documents are handled with standard vocabulary. Data is independent from applications and can be exchanged within certain domains, e.g. Dublin Core (DC). Step 3 pertains to RDF (Resource Description Framework) taxonomy and documents with different vocabularies. Data is classified by hierarchical structured taxonomies, e.g. RDF. At Step 4 OWL ontologies are applied for automatic reasoning. New data can be generated through rule-based reasoning, e.g. automatic cross-domain document transformation.

In technical detail, Semantic Web has a set of languages and standards. I conclude Semantic Web technologies in 5 language categories as depicted in Figure 3.5. The aforementioned Step 2 and Step 3 can be considered as one modeling phase with XML and RDF as modeling languages. Related schemes are applied to support the modeling languages. At Step 4 two categories of languages are used to process Semantic Web information: rule languages and query languages.

With the rise of Web 2.0 recently, Semantic Web 2.0 is also coined [Grea07] as a topic which should be observed with the development of social software and Web 2.0. Figure 3.6 shows the architecture of Semantic Web [Bern98] on the right. I extend the Web 2.0 elements on the left part for a comparison. They both employ XML for data modeling on the lower level. On Web 2.0 users may take more control than on Semantic Web. The application

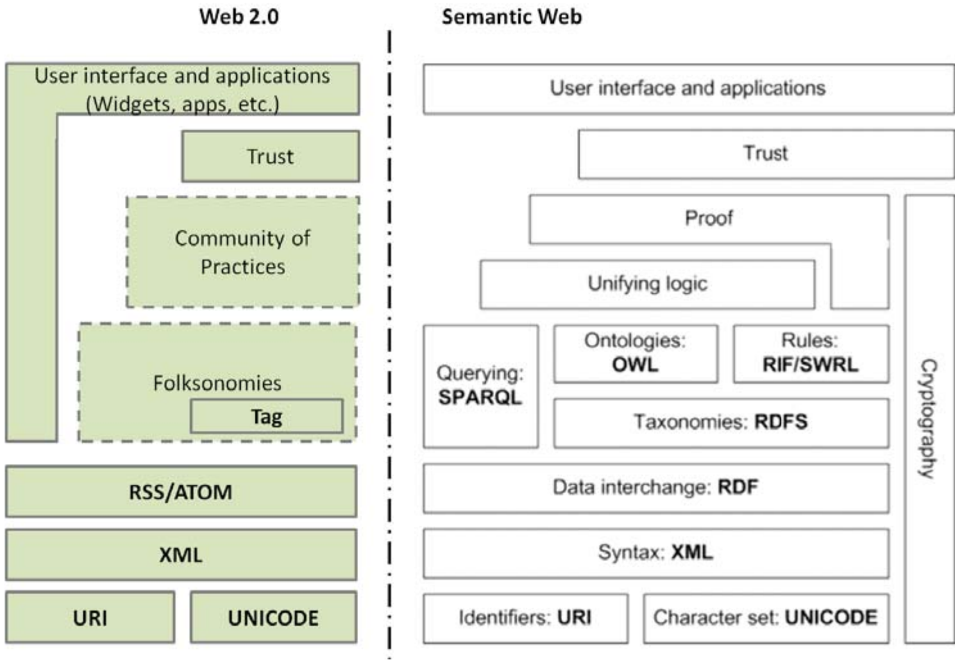

Figure 3.6: Web 2.0 architecture vs. Semantic Web architecture (extended from [Bern98])

of user-generated tags enrich semantics greatly. I describe the components *Folksonomies* and *Community of practices* in dash lines for the hyperthesis of my dissertation that these two components are the appropriate approach to achieve certain trust of user interface and applications.

3.2.3 Cross-platform Information Diffusion

Another issue on Web 2.0 is the cooperation between information, platforms, and users. As depicted in Figure 3.7, the current Web 2.0 consists of many platforms and social aggregation transfer diverse SNS media including services and content created by user communities and integrate them into one platform. According to the current information management on the Web 2.0, the four aspects social network analysis, cross-media analysis, social pattern recognition, and identity management are proposed to enhance interoperability among user communities, Web 2.0 media, and platforms. Not only different media is dealt with in a cross-platform manner, but also social networks need be analyzed across platforms. Hence, social pattern analysis as well as social network analysis should be employed to draw a social graph on it. Identity management is the key to fulfilling cross-platform information diffusion on cross-platform networks [CGKP08].

Social patterns include similar behavior of members over their social networks. For example, *broker* is one of the social patterns that are useful for cross-platform information diffusion.

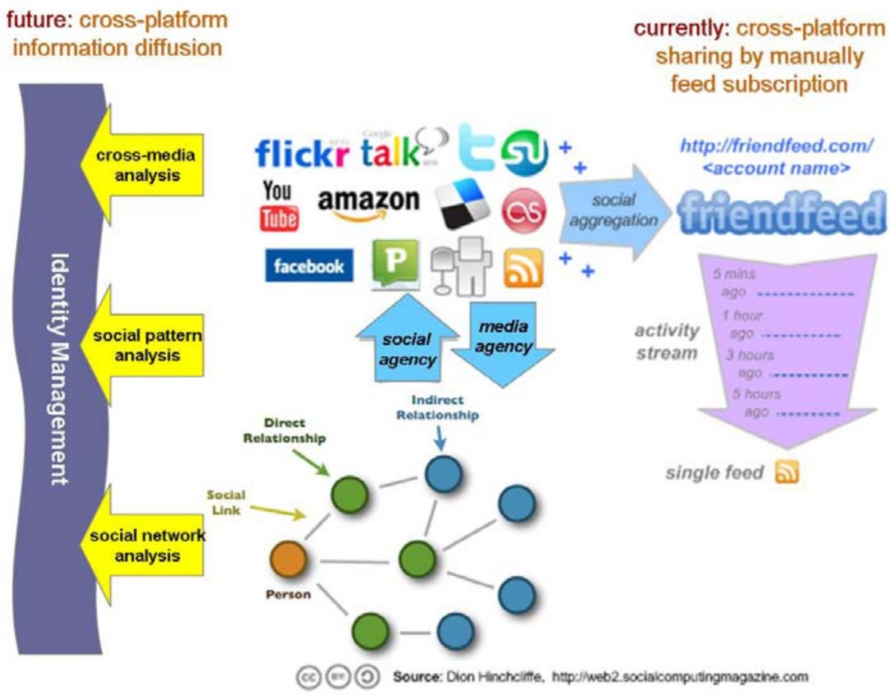

Figure 3.7: Cross platforms for social network sites (adapted from [Hinc08])

The members are brokers, when they transmit knowledge between sub-groups in networks [KiTs07]. The brokers are usually those, who span structural holes that are the relationships between two non-redundant neighbors of the network [Burt92].

The cross-platform information diffusion is carried out with social network data from different sources which are of a private (e.g. private SMS, private chat), a semi-public (e.g. mailing lists, group chats, forums, protected wikis), or a public nature (e.g. blogs, public wikis, public image or video sharing) [KCSp07]. The requirements on the combination of data from the media create the need of cross-media analysis application in the examinations of social networks. Multimedia tagging and annotation play an important role. Social network analysis focuses on the study of in-degrees and out-degrees of a node, i.e. centrality measures. Nodes with the high degree centrality are the most visible in the network, adjacent to the members, and contribute to the identity of the network [WaFa94]. The betweenness centrality identifies how many paths are going through members, how many times they are bridges of information. The Edge Betweenness Centrality (EBC) [FBWh91] is useful to identify network subgroups and to recognize social patterns.

Microsoft Live ID and Google accounts first brought identity into sight. The concept of identity is of great importance in digital social networks. One of the implementation examples is the standard of OpenID. The standard has been developed from a lightweight HTTP based URL authentication framework to an open community-driven platform [ReRe06]. Started with 9 million users on LiveJournal.com for bloggers, more and more social network sites support OpenID. The most significant benefit is to enable single-login, so that users need not register to a new service with another set of user name and password. Users might question how safe it would be to sign in each social network sites to access personal mail box with the same user name and password. So far, OpenID is an efficient method to identify users across platforms. What will happen, if one's OpenID is once stolen? A personal identity repository can be established, if email addresses are traced. However, these emails are not allowed to be used for further purpose. In short, security, privacy and trust of OpenID are particularly critical.

3.2.4 Rich Internet Application and Mash-ups

Along with the theories and concepts above, some implementation technologies are introduced here. Rich Internet Applications (RIA) aim to provide intuitive user interfaces and complex applications, which are platform-independent and widely accessible in the Internet. The term was coined by Macromedia in 2001 and described as an appealing, interactive, slim, and flexible web application [Alla02]. RIA became much more popular with the introduction of Flex 2 by Macromedia in 2006.

Adobe promotes RIA technologies greatly. Adobe Flash is an authoring environment for creating rich, interactive content for the web, intended for creating animations, games, or branded interactive marketing content. Adobe Flex is a cross-platform development framework for creating RIAs, especially for complex interactive web apps such as branded, multimedia-rich enterprise, e-commerce, or productivity apps. Currently, Adobe has released Flex 4 [TLBT08]. Other technologies to create RIAs are Ajax [Garr05] or Microsoft Silverlight[2].

RIA embeds user interface functionality of desktop software applications into browsers. Such low-cost deployment of Web applications can reach wide user communities. Multimedia communication interactivity is enhanced. Further benefits include:

- Increased revenue: more online transactions are due to speed, task completion rate, and return.
- Increased differentiation: more intuitive, customized, and compelling access to services are enabled.
- Engaging experience: the narrative is beyond what simple HTML can provide.
- Increased understanding: from complex business information to understanding trends in statistics, RIAs help a user understand content in a visual and interactive way.
- Reduced support costs: more usability and fewer errors lead to fewer support calls.

[2] http://silverlight.net

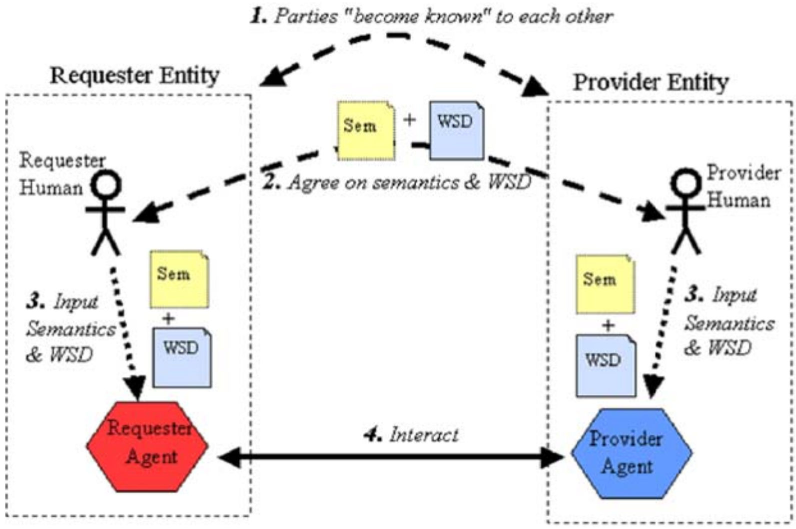

Figure 3.8: Web service architecture [BHM*04]

Another term *mashup* stands for a website or application which combines data and functionality of different services to create a new service, e.g. visualization of restaurant locations using Google Maps [Adam09].

3.2.5 Web Services and SOA

Web Service is a stand-alone software component with a unique URI and operates with each other over the Web, as depicted in Figure 3.8. *Service Oriented Architecture* (SOA) [Burb00] is a component model that delivers application functionality as services to end-user applications and other services, bringing the benefits of loose coupling and encapsulation to enterprise application integration.

The definition of *Service Oriented Architecture* is highly related to business/enterprise applications. From the technical point of view, SOA is like any other distributed software architecture in that it enables everybody to build applications that use components across separate domains boundaries. However, SOA is also unique in way that incorporates those factors that are critically important to business: service reliability, message integrity, transactional integrity, and message security [Hasa04]. SOA is an architectural style with the goal to achieve loose coupling among interacting software agents. A service is a unit of work done by a service provider to achieve desired results for a service consumer. Both provider and consumer are roles played by software agents on behalf of their owners (cf. Figure 3.9).

SOA is featured with high flexibility. Services are software components with well-defined

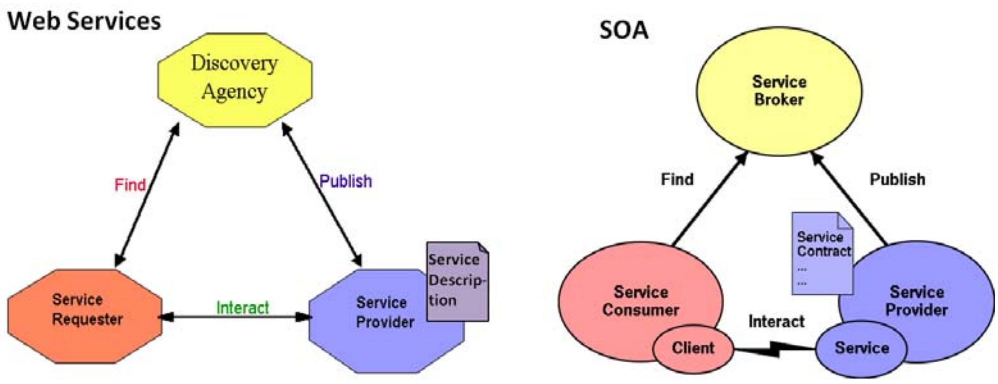

Figure 3.9: Web service architecture vs. service oriented architecture [BHM*04]

interfaces that are implementation-independent. An important aspect of SOA is the separation of the service interface from its implementation. Services are consumed by clients that are not concerned with how these services will execute their requests. Services are self-contained to perform predetermined tasks and loosely coupled for independence. Services can be dynamically discovered. Composite services can be built from aggregates of other services.

During the recent years, service-oriented design is becoming more popular. Service orientation retains the benefits of component-based development (self-description, encapsulation, dynamic discovery, and loading), but there is a shift in paradigm from remotely invoking methods on objects, to one of passing messages between services. A service is generally implemented as a course-grained, discoverable software entity that exists as a single instance and interacts with applications and other services through a loosely coupled, message-based communication model.

Meanwhile web services have evolved as the best means of achieving SOA. Web services are distributed software components which can be accessed over the Internet using well established web mechanisms and XML-based open standards and transport protocols such as SOAP and HTTP (HyperText Transfer Protocol). Public interfaces of web services are defined and described using Web Service Description Language (WSDL) standardized by W3C (World Wide Web Consortium) . Web Services are moving Internet from program to user interactions, business to consumer (B2C) interactions, and business to business interactions [GGKS02].

The main idea behind Web Services and SOA is to simplify complex functionality through specifying and employing a set of elementary services. Software itself is the key object. However, it is limited in its flexibility. Service science should be seen as a complete service framework including data services, hardware service. Software as a service (SaaS) and platform as a service (PaaS) are still limited on the level of software. Infrastructure as a service (IaaS) has extended partly to hardware. The target clients could be entrepreneurship, organizations, professional communities.

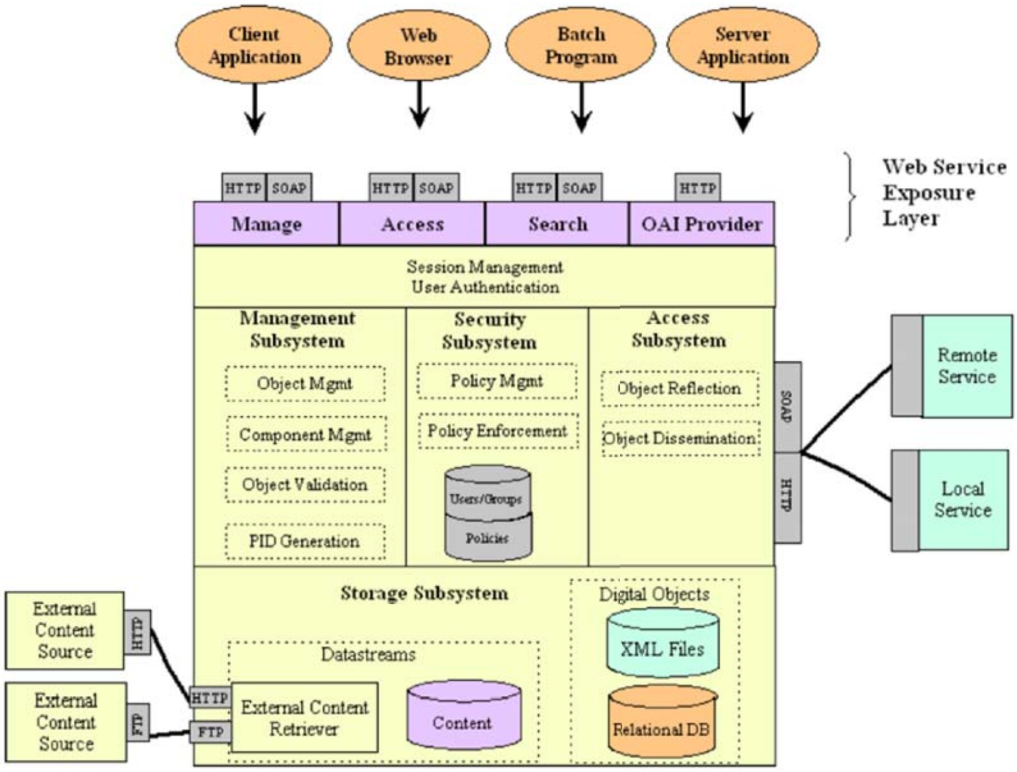

Figure 3.10: Fedora service framework with various subsystems [LPSW05]

The SOA principles are clear, while the realization is more challenging. As an example on the SOA principle, the Fedora service framework [LPSW05] developed at Cornell University aims to provide organizations and institutions appropriate technologies and techniques to create, manage, publish, share, and preserve the world's information. The information management concept behind can be summarized as *sustainable* information management, which requires durable access, interconnection of related information, minimal complexity, and trusty access. Figure 3.10 illustrates the n-tier architecture of the Fedora service framework.

3.3 Context Awareness for Mobile Information Systems

Mobile devices create a vast amount of information about knowledge, users' behaviors, context, and feedback etc. Moreover, mobile information systems change the information exchange and communication approaches among mobile users. Contextual information is the added-value in mobile information systems, in comparison to the Web 2.0 platforms.

3.3.1 Context

Context is defined by Dey [Dey01] as "any information that can be used to characterize the situation of entities (i.e., whether a person, place or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves." Context is embedded in media tightly and media can only pass messages with help of contextual information.

Baldauf et al. [BDRo07] classify the concept *context* using the dimensions of *external* and *internal*, as well as *physical* and *logical*. Certainly, user context can be related to both dimensions. Much research has been done on external or physical context, which is far more complicated related to different data collected by various sensors such as photodiodes, color sensors, cameras, microphones, accelerometers, motion detectors, GPS, thermometers, etc. When the internal context is added, the complexity for design and realization of context-aware systems is enhanced accordingly.

In [ChKo00] context is categorized into four groups: *computing context* such as network connectivity, communication bandwidth, display size of the end devices; *user context* such as users' preferences, communities which users belong to; *physical context* such as lighting, location, noise levels, and temperature; and *time context* which can be used as timestamps to identify the records of a context history. Context is widely considered as technical profiles of devices, especially refers to those handheld devices with limited capacity. Hence, context-aware adaptation is related to devices [TJHe09]. Zimmermann et al. [ZLOp07] classify context in time, location, individual, relations, and activities. They further give context an operational definition through discussing about operations of context changing.

Dynamic aspects of context include environmental, spatial or location-related, temporal, domain-related, and even community-related [CKHJ08]. All these definitions attempt to establish a realization framework for context modeling.

Several definitions of *context* have been associated with uncertainty, such as unclear knowledge, lack of clarity of accuracy, lack of information, errors, inaccuracies in the device, and failure of technology [DFCo09]. Uncertainty is generated from presence of uncertain, ambiguous or incorrect contextual information. It directly affects user confidence and can cause the application to become useless. Damian et al. [DFCo08] categorize three different notions of uncertainty in context:

- Uncertain Context: it occurs when the application malfunctions. It generates doubt in the user about the validity or quality of the information, e.g. difficulty to interpret actual location [BeSt07], information of locations disappearing and reappearing in different places [BCF*06].
- Ambiguous Context: contradictions, violations of rules or inconsistencies are situations in which ambiguous context is generated. For example, [BeSt07] mentioned that the representation of the information is sometimes very abstract and difficult to relate to the real world, which hampers user's interpretation.
- Wrong Context: refers to accuracy and precision of the sensors, devices or technologies used to obtain context.

Context detection is often carried out in mobile applications and it also contributes to handling uncertain context information. In many cases, detection of erroneous knowledge cannot be checked via certain processes or schema. Zimmermann [Zimm07] establishes a context management framework of interaction on context-aware systems from different context actors comprising developers, domain experts, authors and end-users in his dissertation, though uncertain context is not handled. I argue that users' involvement can be taken into account for uncertainty handling as well. One of the most practical and effective methods is *cooperative sharing interpretation* of erroneous knowledge [NoTa95, Klam00]. This *cooperative sharing interpretation* is based on certain context information which needs a great amount of multimedia data [Klam00].

3.3.2 Context Modeling

A set of parameters are usually applied to describe different types of contextual information. A complete parameter set specified in [BDRo07] consists of *context type*, *context value*, *time stamp*, *source*, and *confidence*. Context type and context value are the main context parameters and information. Context type can be refined into different sub categories. Several examples about the information in pair are listed as follows:

```
(environment:temperature, cold)
(environment:light, bright)
(device:type, iPhone)
```

These three other parameters are related to data uncertainty issues.

- *Time stamp* specifies when the context information is sensed or collected, e.g. `(environment:temperature:timestamp, 16.01.2010 0:29)`
- *Source* tells how context information is collected or which sensor or device is employed, e.g. `(environment:light:source, 50 Hz)`
- *Confidence* describes exactly the uncertainty of this context information. In most cases it is related to the confidence or accuracy of the source, e.g. `(environment:location:source:confidence, 97.5%)`

In order to enable efficient context-aware adaptation, context information must be at first collected and presented to the application. Therefore, a common representation format for context information is required [HBSc02]. A well-defined context model is needed to define and store context data in a machine readable form in order to enhance interoperability. Strang and Linnhoff-Popien [StLi04] survey several context-aware systems and compare the most relevant context modeling approaches including *Key-Value*, *Markup Scheme*, *Graphical*, *Object-oriented*, *Logic-based* and *Ontology-based models*. These approaches are based on different data structures and represent context information for machine processing and reasoning.

According to the analysis result only the ontology-based modeling approach fulfills assets for context modeling in mobile computing environments [StLi04]. In the field of knowledge management the term *ontology* refers to the shared understanding of a set of entities, relations, and functions. Ontologies are promising to model contextual information because of the powerful and formal expressiveness. Ontologies offer the possibilities for context representation and reasoning. Among many context-aware frameworks, Roussaki et al. [RSK*06] indicate that ontology-based models are interoperable and flexible context representation schemes. They are necessary to support efficient context interpretation and reasoning for distributed large-scale context-aware systems.

Wang et al. [WZGP04] give three arguments for developing context models based on ontologies: knowledge sharing, logic inference, and knowledge reuse. The ontology-based context modeling method with first-order predicate calculus represents contextual information in the form of `predicate(subject, value)`, in which:

- $subject \in S^*$: the set of subject names (e.g. a person, location, or object);
- $predicate \in V^*$: the set of predicate names (e.g. "is located at" or "has status");
- $value \in O^*$: the set of all values of a subject in S^*.

As a prevalent and efficient context modeling approach, ontology-based context modeling is also applied in my framework with details in Section 4.2.2.

3.3.3 Context Awareness

When context information is applied in information systems, those systems or their users are aware of the contextual information as well. Context-aware applications are able to increase the usability and effectiveness by adapting their behavior according to the current contextual information. In other words, a context-aware service can sense users' current context and adapts its content to users' needs [PaAl06]. Here *behavior* is understood as system features or functionalities. Hence, context-awareness is a key success factor for both system developers and users to gather contextual information and adapt system's behavior correspondingly. Among the others, context-aware adaptation is one of the most important features for context-aware mobile information systems to meet the varying requirements of different clients [HBSc02, Pasc98].

Location-aware systems are the main sub category of context-aware applications. The widespread sensor technologies such as GPS make location-aware applications a part of everyday life [HSKr04]. Generally speaking, location-aware systems cover a large range of context-aware mobile information systems [LLXZ02]. Baldauf et al. [BDRo07] gives an in-depth survey of the existing location-aware systems with the technologies applied. In recent years, development of location-aware systems have the following new directions and challenges:

- Indoor localization is also needed. GPS technologies have been developed rapidly. The accuracy of localization has been enhanced greatly. A lot of location-aware information systems can make good use of GPS technologies, which is limited to outdoor areas. Indoor location awareness raises more interest. Rapid development in RFID, near field communication (NFC), and WiFi technologies contribute to enhance indoor location awareness.

- New approaches to context modeling are focused, which raises challenges for data management both for outdoor and indoor applications [JLYa10].

- Location is associated with communities and location-aware tagging is prevalent. Multimedia tagging systems demonstrate this. Information about where the image is tagged and who tags this image is interested to users as well.

- Mobility is the key to good location-aware systems. Location awareness is reflected almost in many mobile applications. The history and changes of locations are paid attention. Much research is conducted in moving object data management [JLOo07].

Other contextual information is additionally taken into consideration in some state-of-the-art systems. For example, information for user community is a significant aspect to design context-aware systems, which is neglected in many context-aware systems. In [KSCa06b] community context is adopted based on fundamental contextual information such as community members' preferences, location, time, device capabilities, and so on.

3.3.4 Mobile Web Services

Mobile applications have been developed as standalone applications, mobile Internet, mobile mashups, gadgets, and mobile integration of complex information systems. The history of mobile applications is short but changing rapidly. Mobile applications can be applied in a large scope of domains, such as e-tourism or mobile learning. Much research has been done in mobile learning, which focuses on empirical study and users feedback on using the systems in field trips [Ojal09].

Smartphones are becoming pervasive and are being used in a wide range of applications such as location-based services, mobile banking services, ubiquitous computing, etc. The higher data transmission rates achieved in wireless domains with Third Generation (3G) and Fourth Generation (4G) technologies and the fast creeping of all-IP broadband-based mobile networks also boosted this growth in the cellular market. This situation brings out a large scope and demand for software applications for such high-end smartphones.

Although mobile commerce poses to bring tremendous opportunities, we have to be cautious and understand the risks. Historically, technology adoption has never been a smooth or linear process in cellular domain. Only recently, the Java technology is emerging as one of the most important enablers for mobile enterprise solutions. All major mobile device vendors including Nokia, Motorola, Siemens, Samsung, Fujitsu, Mitsubishi, NEC, Panasonic, and Sony, have adopted Android platforms as part of their core strategy for future smart devices. Major wireless carriers such as NexTel, SprintPCS, and AT &T have committed to support Java devices and applications on their networks. Moreover, the communication between mobile nodes involves proprietary and application-specific and terminal-specific interfaces.

To meet the demand of the cellular domain and to reap the benefits of the fast developing web services domain and standards, the scope of the mobile terminals as both web services clients and providers is observed. Mobile web services enable communication via open XML web service interfaces and standardized protocols also on the radio link. To support the mobile web services, there exist several organizations such as Open Mobile Alliance (OMA), Liberty Alliance (LA) on the specifications front; some practical data service applications such as OTA (over-the-air provisioning), application handover etc. on the commercial front; and SUN, IBM toolkits on the development front. Thus, though this is still at an early stage, mobile web services have a long road ahead. Mobile terminals accessing the web services cater for anytime and anywhere access to services. Some interesting mobile web service applications are the provisioning of services like e-mail, information search, language translation, company news, etc. for employees who travel frequently. There are also many public web services accessible from smartphones such as weather forecast, stock quotes, etc. Mobile web service clients are also significant in the geospatial and location-based services [BeMa03].

While mobile web service clients are in common, the research on smartphones' providing web services is still sparse. The scope of mobile web service provisioning was studied by two projects at RWTH Aachen University since 2003 [GAZW07, SJPr06], where Mobile Hosts have been developed, capable of providing basic web services from smartphones. The Mobile Host was developed in PersonalJava, later had been upgraded to J2ME, on a SonyEricsson P800 smartphone. Open source kSOAP2 was used to create and handle the SOAP messages. Once the Mobile Host was developed, an extensive performance analysis was conducted, proving its technical feasibility [SJPr06].

Moreover, Mobile Hosts enable seamless integration of user-specific services to the enterprise [SrJa09]. Services provided by the Mobile Host can be integrated with larger enterprise services bringing added value to these services. For example, services can be provided to the mobile user based on his up-to-date user profile. The profile details like the device capabilities, network capabilities, location details, etc. can be obtained at runtime and can be used in providing most relevant services like maps specific to devices and location information.

With the development of mobile cloud computing [KRKC10] very recently, resources existing in the cloud facilitate mobile applications and services well. Hence, mobile web services might not be required to be powerful anymore. Experiences of standard-based development of mobile web services are also important for further employment of service communication standards, e.g. Extensible Messaging and Presence Protocol (XMPP) [ReKl09].

3.3.5 Existing Context-aware Applications

Among many other systems such as GUIDE [CDMF00b] and CRUMPET [SNPZ02] etc., a survey of a location-aware system COMPASS [VPKo04] and a personalized adaptation system URICA [MCCL06] are briefly introduced as follows.

COMPASS on 3G (GPRS, UMTS) and GPS technologies provides guide services to tourists [VPKo04]. For example, when they do not know their ways to the restaurants, museums, shops, public services, etc., COMPASS can help them navigate. It provides an interface so that users can use third party map services such as Microsoft Mappoint. The mobile device can be positioned either via the mobile networks or via the GPS receiver. Depending on users' requests an updated list of buildings or other objects nearby is rendered on the map, when users are traveling to a new place.

URICA (Usage-awaRe Interactive Content Adaptation) [MCCL06] is a usage semantics based content adaptation system. It provides an automatic technique for content adaptation to mobile devices. In URICA users can take part in the adaptation process and make changes until the content is suitably adapted to their requirements. The user's modification towards the adaptation system is learned by the system. Thus, it can adjust its prediction to future accesses of other users.

In general, COMPASS is a context-aware system based on location context, while URICA is mainly based on individual users' context for personalized content adaptation. But the important temporal and community context information is not considered. Both context-aware systems employ the pull mode to deliver users information on request. In contrast, there are push mode context-aware systems such as a context-aware messaging service developed by NTT Japan [NMSa06]. Users get SMS message automatically from the providers according to their location. In addition, compared to adaptive recommender systems in which user preferences are decisive factors in the content selection process, the existing context-aware systems rarely use community preferences as a determinant factor to the content adaptation. In fact, users not only gain access to content based on their individual preferences but also benefit from the experiences achieved in the community they belong to. Here community context includes community preferences, community tasks, community activities, and so on. In addition, uncertainty issues are not covered and multimedia support is limited in these systems.

3.4 Multimedia Services

Multimedia is defined by the Cognitive and Technology Group at Vanderbilt University [Cogn93] as "linkage of text, sound, video, graphics, and the computer in such a way that the user's access to these media becomes nonlinear and virtually instantaneous." An example for multimedia is the World Wide Web (WWW). Software pieces to process multimedia serve as multimedia services such as multimedia messaging services and video processing services. In this section, multimedia annotation and storytelling services are focused on.

Furthermore, multimedia information systems deal with problems in the multimedia research fields including design, learning and user interfaces among users, multimedia, and multimedia applications [StNa04b]. Processing of multimedia data is more complicated than text data because multimedia data is continuous, multiply compositionable and decompositionable in spatio-temporal aspects. Meanwhile, mobility is required to enhance the connection of multimedia data to the real world. Mobile multimedia information systems target at processing mobile multimedia which is shared and managed via mobile networks.

Since the Semantic Web [DFHa03] and the Semantic Web Service communities [CaSh06] have become aware of multimedia semantics, these research communities have developed solutions for the explicit management of context and multimedia semantics. Semantic technologies comprise multimedia metadata standards which are appropriate to describe multimedia semantics.

3.4.1 Multimedia Metadata Standards

As the outreach and scale of the information systems grow, requirements for better performance, reliability, portability, scalability of information systems are more and more important and critical. The requirements also shape the main measurements to evaluate an information system. Besides the hardware enhancement data standardization is a potential method to meet these requirements. It can enhance data reliability, make data portable on different software or hardware platforms, make data available by different information systems in various scales, and enhance system performance as a result. Generally speaking, the issued standards are called metadata, data about data, which gives information about data at administrative, preservative, descriptive, technical, and usage levels [Gill03].

Metadata is supposed to fulfill tasks such as identifying items uniquely worldwide, describing collection items including their *contexts*, supporting retrieval and identification, grouping items into collections within a repository, recording authenticity evidence, facilitating information interchange between autonomous repositories, etc. in the domain of digital objects preservation [Glad07a].

Multimedia metadata fosters expression of multimedia semantics. Employment of metadata standards aims at enabling data exchange with enhanced data interoperability. However, different metadata standards enhance data interoperability to a certain extent. Metadata standards facilitate data with an effective means to create, describe, search, and retrieve multimedia data. Incompatibility still exists because of a high variety of multimedia standards. Those terms like *meta-metadata* are coined or crosswalks among different metadata standards have been attempted. It is trivial to specify crosswalks among different metadata standards. Since a mapping is needed in any two of metadata standards, it could be impossible to derive the mapping by a transitive means. Moreover, information loss and imprecise mapping might still lead to data uncertainty problems or unexpected consequences.

The organizations for standardization might be official organizations recognized by countries, and industry-led organizations which may or may not have collaboration with official bodies as well. Some organizations are responsible for a certain region such as the American National Standards Institute (ANSI), which is an official organization and working on standardization in U.S. Some are for certain research fields and of the industry-led type, e.g. the Institute of Electric and Electronic Engineers (IEEE). In addition, a great number of organizations and institutions are working on standards in information systems, such as the World Wide Web Consortium (W3C), the Organization for the Advancement of Structured Information Standards (OASIS), and the International Organization for Standardization (ISO). ISO is a non-government organization which is responsible for developing and deploying standards in various scientific fields. Its members come from 162 countries worldwide and create standards on an international scale. The process of standardization gets along with requirements for standards, specifying of standards, approval and adoption of standards and deployment of standards. Moreover, standardization is often a compromise concerning political, technical, and financial considerations [KSJ*06b].

Purposes of metadata standardization in information systems are interoperability, interpretability, exchangeability, and sustainability of information among others:

- Interoperability in the context of information describes interactions between digital information, and meanwhile leads to the question how individual metadata standards as well as domain-specific standards can be combined into coherent families of standards [KPSc98].
- Interpretability tells how information is defined, represented, and managed by means of a certain kind of metadata. At the same time, it includes the translation of information from one metadata to another one as well.
- Exchangeability warranties information exchange between different information systems which describes the compatibility among individual metadata standards.
- Sustainability is required by development and reusability of information and its metadata.

Standards in information systems are both standards for information itself, namely metadata standards, and standards for information systems, also called information infrastructures in certain contexts. These purposes above are carried out on the base of the information level. Metadata standards describe how digital items are defined, processed, and stored. And they are diverse according to the field of origin or sector the digital item is related to, such as a digital image of a library or a museum object, a digital representation of geospatial entity or e-learning content. In the field of cultural heritage management (CHM), for instance, metadata standards clarify the relation of the virtual digital item and its association to the real physical world.

In geographic information systems (GIS) metadata standards are the result of complex and tedious negotiation processes on an international scale. As in many other areas of application of information systems, the usage of different data sources as well as different data representations such as videos and audios cause heterogeneity of data that is to be managed. For that purpose, standards are used to harmonize the data on a regional, national, or even global level. Responsible organizations and institutions are also structured by industry-led or official level such as the industry-led Open Geospatial Consortium (OGC), and the official organizations, the Infrastructure for Spatial Information in Europe (INSPIRE) and the Global Spatial Data Infrastructure (GSDI). Geographic standards have been widely deployed in applications for cultural heritage management. In this research field great efforts have been made to specify the description of cultural heritage and to apply the existing standards [DKJa05].

Digitalization efforts with versatile categories for cultural heritage in individual countries can be traced back to the late 1970's. Since that time standardization has concentrated mainly on the digitalization methods for compilation and retrieval of physical museum collections. This has led to a wide variety of national standards for museum collections and their digital representation such as SPEKTRUM developed by MDA, the agency for documentation and management of museum collections for the United Kingdom. However, a temporal factor is important for cultural heritage categories to distinguish built heritage, archeology, and current, and past landscapes [Lee05]. And geographic hypermedia standards are especially crucial in this context. The political dimension of cultural diversity and the need of the information society are illustrated in the declaration of the European Union "Lund Principles" of 2001[3]. Members stated clearly to coordinate digitalization efforts and to report and publish them yearly.

There exists a large variability of multimedia metadata standards. Multimedia Content Description Interface (MPEG-7) standard [Kosc03] is one of the richest multimedia content description standards with a comprehensive schema. MPEG-7 is able to express multimedia content covering the most important media aspects including low-level technical information and high-level content semantics. The semantic information expressions may distinguish multimedia creators from the depicted people in a picture or a video clip. MPEG-7 can also be easily used with other metadata standards together, due to its flexible schema. Besides those advantages, MPEG-7 has limitations in semantic expressiveness. Although it has defined many semantic tags, it is still impossible to cover semantic information across different domains. Thus, in different domains several metadata standards can be prevalent in use, such as Dublin Core (DC) for digital libraries or digital information preservation [Glad07a]. Metadata standards are also used for multimedia adaptation straightforwardly, e.g. TV-Anytime [ETSI05] for adaptive personalized TV programs. The widely spread metadata standard EXIF describes the low-level technical, device, and semantic information such as creation information of images.

In Figure 3.11 the multimedia metadata standard MPEG-7 is used and a corresponding MPEG-7 schema is specified based on the comprehensive MPEG-7 multimedia schema. The aforementioned ATLAS media theory is applied. This process to map multimedia documents to ontology is called localization (1). In contrast to structures of ontology-based systems, the underlying ontology is interpreted or transcribed (2) by the structure of the MPEG-7 schema itself. As before transcription (3) of multimedia (MM) documents can be done quite easily in multimedia concepts with the difference that documents are now compatible to MPEG-7. That allows us to combine the advantages of a loose categorization for computational processing with the concepts of unclassified metadata annotations, as it is needed for the tight interplay between the organization of knowledge and communicative processes within the community of practice. After that, all data is localized (4) in an XML database. From there it is accessible to all users in a final (re-) addressing (5) process. One can use a multimedia domain specific metadata description language like MPEG-7 to describe all the available information and then to map it on an ontology later. There is no ontology-like semantics for media but only an operational semantics.

[3]http://cordis.europa.eu/ist/digicult/lund-principles.htm

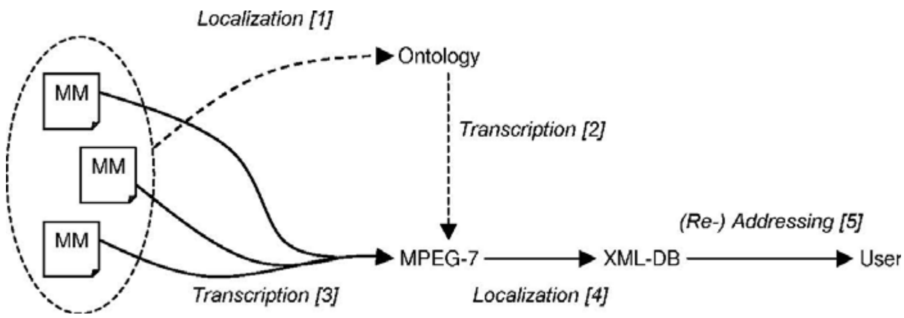

Figure 3.11: Ontology-based multimedia data processing [SKJa02]

In order to model such complicated data, several eminent standards in the field of cultural heritage management are introduced as follows.

CIDOC

The International Committee for Documentation of the International Council of Museums (ICOM-CIDOC) is the international group for the documentation of museums and similar organizations. Aiming at gathering, management, and sharing of the knowledge carried in heritage collections, CIDOC provides a discussion forum to provide advices on the application of documentation standards as well as information and communication technologies [Doer05]. There are mainly the following standards that have been widely used in the field of archeology and for museums:

- CIDOC Standard for Archaeological Sites and Monuments
- CIDOC Standard for Archaeological Objects
- CIDOC International Guidelines for Museum Object Information
- CIDOC Information Categories

These standards specify what attributes may be used to describe a cultural heritage object and what terms may be allowed to use. They are data about real cultural heritage objects, so-called meta-object, and are also a kind of metadata. Hence, the CIDOC Concept Reference Model (CRM) has been developed to allow interoperability "not only on the encoding level (...) but also on the more complex level semantics level". It was on vote as Draft ISO Standard (ISO 21127) until February 2002 and is developed as core ontology model for capturing common semantics of heterogeneous data structures in order to support their semantic integration [Doer05]. This standard is, however, text-based and cannot describe multimedia data properly. So some proposals have been submitted to use multimedia standards in CRM. For example, Hunter has proposed a mapping model between CIDOC CRM and MPEG-7 in [Hunt02].

MIDAS

The Monument Inventory Data Standard (MIDAS) [FISH07] is a content standard that sets out what sort of information should be recorded, for instance, information to describe the character or location of a monument. It was developed mainly from 1996 to 1998. The latest revised version was proposed in December 2003 which covered CIDOC-CRM issues. MIDAS defines an agreed list of the units of information, also called metadata elements, which should be included in an inventory or other systematic record of the built historic environment. These units of information are grouped together in schemes and cover areas such as monument character, events, people and organization, spatial data etc. It is developed by user communities in the field of conservation and promoted by English Heritage, the advisory body of the English Government for the historic environment. As a text-based standard it generally does not support the production, presentation, and dissemination of digital images or GIS technology [FISH07]. This point would be considered in the next revision of the standard [Lee05]. Nowadays MIDAS is managed by the Forum on Information Standards in Heritage (FISH) established in 2000. It is a platform for software developers and standardization professionals with the goal of the interoperability and exchange in the heritage sector.

Object ID and Core Data Standard/Index of Getty Information Institute

Object ID is an international standard for describing cultural objects initiated by Getty Information Institute in 1998. It has been developed for art and antiques through the collaboration of the museum community, police and customs agencies, the art trade, and insurance industry. The standard was defined by a combination of background research, interviews, and by major international questionnaire surveys. It is also text-based and not suitable for describing multimedia information. It has a close relationship to the Core Data Index and the Core Data Standard, because the element sets are similar. So the interoperability among these three standards is enhanced as they are used for different cultural heritage categories.

The Core Data Index to Historic Building and Monuments of the Architectural Heritage was defined by a working group with members from heritage organizations in Europe and was approved in October 1992. It specifies a minimal set of data elements to describe architectural heritage. This standard establishes consensus over 137 architectural inventories or description by 78 organizations in 26 countries [ThBo98]. Documents of this standard comprise content such as photographs and archives, environmental files, biographical materials and so on. The information is all text-based and does not support multimedia descriptions.

The Core Data Standard for Archaeological Sites and Monuments was specified by the archeology documentation group of the Council of Europe in cooperation with the ICOM-CIDOC. It was published in 1995 and can be linked with the CIDOC standard for archaeological

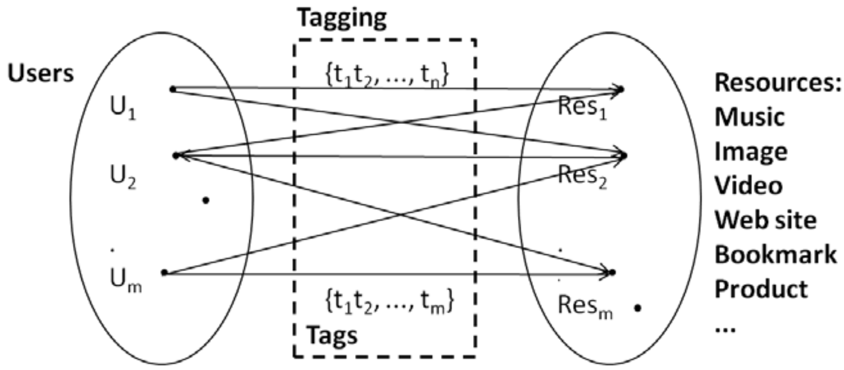

Figure 3.12: The Web 2.0 tagging model (adapted from [LaAu06])

objects issued in 1992 and CIDOC's International Guidelines for Museum Object Information issued in 1995. This standard specifies a core data set to inventory and to document archaeological heritage. It has a close relationship to the Core Data Index to Historic Building and Monuments of the Architectural Heritage. Due to their immanent relation, the Core Data Index and Core Data Standard are similar.

3.4.2 Tagging

Many researchers ask the question "what benefits Web 2.0 can bring to multimedia research" [Boll07]. With the rise of Web 2.0, the word *tag* has been used in almost every Web 2.0 or Web page. Tagging was the most important feature Joshua Schachter added to the social bookmarking platform Delicious. Rather than using a standard set of categories defined by experts, everybody creates one's own categories in the form of tags. Schachter's original idea is to share his big collections of bookmarks with his friends, which is a common practice in communities.

The conventional tagging model is based on three main elements: users, resources, and tags [Hale08]. The community aspect is not covered. Thus, a general tagging model as depicted in Figure 3.12 is a tripartite network [LaAu06]. Tagging activities are mappings between users and resources labeled by different tags. Resources on Web 2.0 comprise various multimedia including music, images, videos, blogs, news, bookmarks, online products, etc.

The emergence and development of a collection of tag clouds form the *folksonomy* instead of taxonomy. Folksonomy is conceptual structure (taxonomy) created by people (folk). Folksonomies are featured with user-generated structures and dynamics, which can be used to rank resources, predict trends, and exploring tag networks [CSB*07].

Hotho et al. [HJSS06] defines folksonomy as a tuple:

$F = (U, T, R, Y)$

where U, T, and R is a set of *users*, *tags*, and *resources* respectively.

Y is additionally a ternary relation: $Y \subseteq U \times T \times R$.

Tagging helps users collect, find, and organize multimedia effectively. Web 2.0 tags can be available to all online users, user community groups, or only accessed by the creator privately. The sociability grade is different. Folksonomy formed by social tagging can even make good use of collective wisdom [MNBD06]. Research on tagging covers information architecture, social software, and personal information management [Smit07]. These three areas are aligned with the categorization of metadata uncertainty dimensions proposed by [SGT*04] as well.

Zoller summarizes the functions of tags as identifying what or who, identifying what it is, identifying who owns it, refining categories, identifying qualities or characteristics, self-reference, and task organizing [Zoll07].

Recently, Geo-tagging has found more applications. In many online newspapers, the location of the news is geo-tagged and visualized in a map, as shown in Figure 3.13. Tags can have a wide use category. Many mobile augmented reality applications are also related to tagging, tagging the reality or the physical world. Tags are recognized according to the physical objects automatically and given as an augmented layer in the mobile applications.

Sawant et al. [SLWa11] extend the activity of annotating into tagging, commenting, and rating. They surveyed over 200 papers to research on image semantic enhancement through social annotation activities. Such activities are also called social input which is the contrast to expert annotations. The interdisciplinary insights and wide coverage of representative literature give a good overview of the state-of-the-art concepts and applications on tagging. According to the content in images to be annotated, four categories of applications are given: concept semantics, person identification, location semantics, and event semantics. Tags for images are related to these four categories.

Experts' annotation activities are stressed, since the existing research has not reached the community level very much. How experts' knowledge enhances multimedia semantics is open. In the existing research and applications, no special tools or services are provided to communities, e.g. expert services to support users' multimedia annotation activities.

In summary, tags are applied to different resources such as images, videos, web pages, blog entries, and news entries. Various web resources are organized through tags. Bookmarking is an activity for resource annotation. Tags can be syndicated in feeds and aggregated into personal customizable spaces or further into social network sites. Figure 3.14 illustrates that tags play an important role in the Web 2.0 information flow.

3.4.3 Digital Storytelling

Digital Storytelling is the modern expression of the ancient art of storytelling. Throughout history, storytelling has been used to share knowledge, wisdom,

Source: http://www.spiegel.de/panorama/0,1518,737411,00.html

Figure 3.13: An example of tagging on an online newspaper

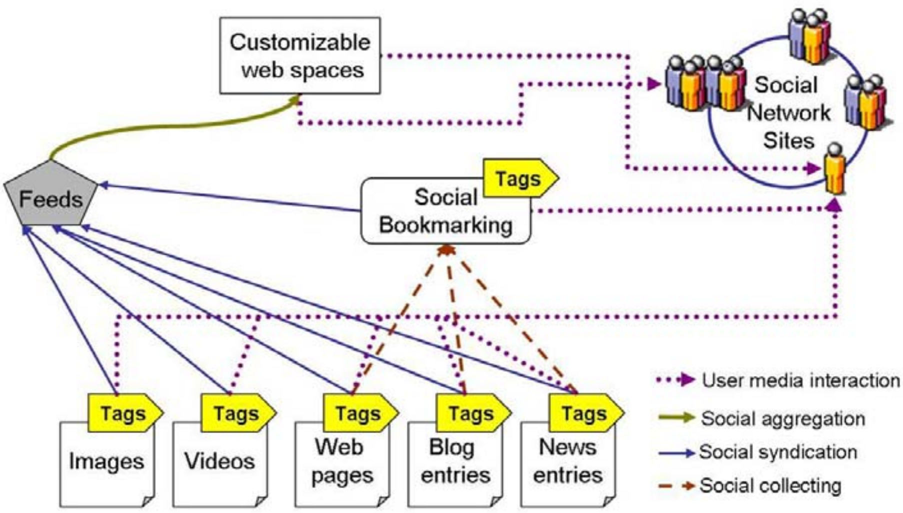

Figure 3.14: Tags for social network sites

> and values. *Stories* have taken many different forms and have been adapted to each successive medium that has emerged, from the circle of the campfire to the silver screen, and now the computer screen. - Digital Storytelling Association

Digital storytelling combines narratives with digital content such as photos, streaming videos, and recorded sounds and produces digital stories usually in the form of a collection of multimedia. Due to its great expressiveness and its capability of being effectively applied to nearly any topic, digital storytelling has been proposed for educational and learning purposes, such as a pedagogic technique, as a tour guide, even as an entertainment means [Robi07, Shar05].

Stories embrace both specific information and general principles which can be applied to particular situations, with regard to different time and places. Brown and Duguid [BrDu00] stated that stories are rich in expressing events sequentially and causally. I extend expressiveness with more features related to the classical 5W1H: who, what, why, when, where, and how. Stories are a good and effective means to represent information as included in Table 3.1.

Expressiveness	**Examples**	**W's**
Sequentially	Firstly this happened, then that	What, when
Causally	This happened because of that	Why
Personally	Somebody made this happen	Who
Spatiotemporally	Once upon a time, in a distant country	When, where
Explainable	This happened in this way	How

Table 3.1: Expressiveness of stories (extended from [BrDu00])

Motivations of storytelling include knowledge creation and sharing for arts, history, and culture in a concise and compact way [KCJa09]. Furthermore, if any error or inconsistency occurs during the storytelling process, it is recognized by the audience easily [BaMu08, Have07]. The rapid development of multimedia technologies has opened up new avenues for making stories on computers [Li07]. Multimedia systems, images, sounds, animations, and texts can be brought together to provide a platform for a large variety of story formats and storytelling forms.

Storytelling is a practical knowledge management activity. The storytelling process provides a navigation model of knowledge as depicted in Figure 3.15. The audience gets storylines based on people, media artifacts, places, and time through the storytelling process.

The value of stories lies not only in telling, but also in retelling. Stories are thus important for learning and education [BrDu00]. Stories can be told to circulate information, to bind people together via shared stories, shared information, and shared interpretation.

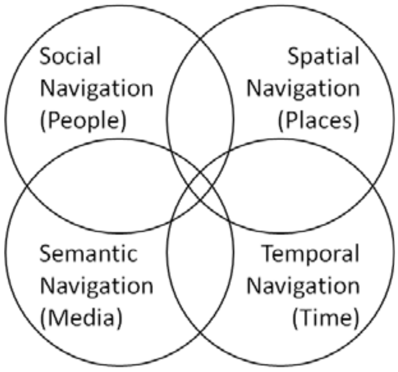

Figure 3.15: Social, spatial, semantic, and temporal modes of navigation (adapted from [Gay09])

A collaborative storytelling process can help design serious games [CPT*09, HLKo09]. Web 2.0 enables every Internet user to tell stories easily, e.g. just to upload some pictures, videos, or slides, which lowers the barriers of media or art access and control greatly. However, the currently prevailing Web 2.0 platforms or social networking sites lack approaches to flexible authoring of multimedia content. The existing technologies produce a great amount of user-generated content, of which no certain purpose is connected with multimedia content. Moreover, the real and hidden motivations of storytelling on the Web 2.0 can help developers design and develop advanced multimedia information systems to meet requirements of the storytelling user communities.

In spite of the same multimedia content, a story can be told in totally different ways. First, sequences of the multimedia content can be organized in diverse ways. Second, the same multimedia content can be shared by or be used to compose different stories. Storytelling is an effective and entertaining approach to passing and embedding certain meaning and certain purposes to multimedia content. Thus, multimedia content has its semantics only if it is used in a context.

Storytelling is an aggregation operation on various multimedia artifacts. People tell stories to make diverse sparse information coherent and associated, which needs context. Stories are not told for general universal, but for certain contexts. A story should have the following elements [Lamb10]: point of view, dramatic question, emotional content, the gift of your voice (meaning the literal author's voice), the power of the soundtrack, economy, keeping it to a minimum, and pacing. Thus, storytelling is a contextualized information processing procedure.

Digital media allows fast creation, sharing, and consumption of interactive content. What makes digital media most suitable for storytelling is the ability to recombine various media types, making stories more effective and interactive. Web-based systems are the ultimate step in the evolution of digital storytelling by making interactive multimedia contents not only available 24/7, but also allowing community-wide distribution.

There are many ways to assess stories and analyze digital storytelling processes. Based on a

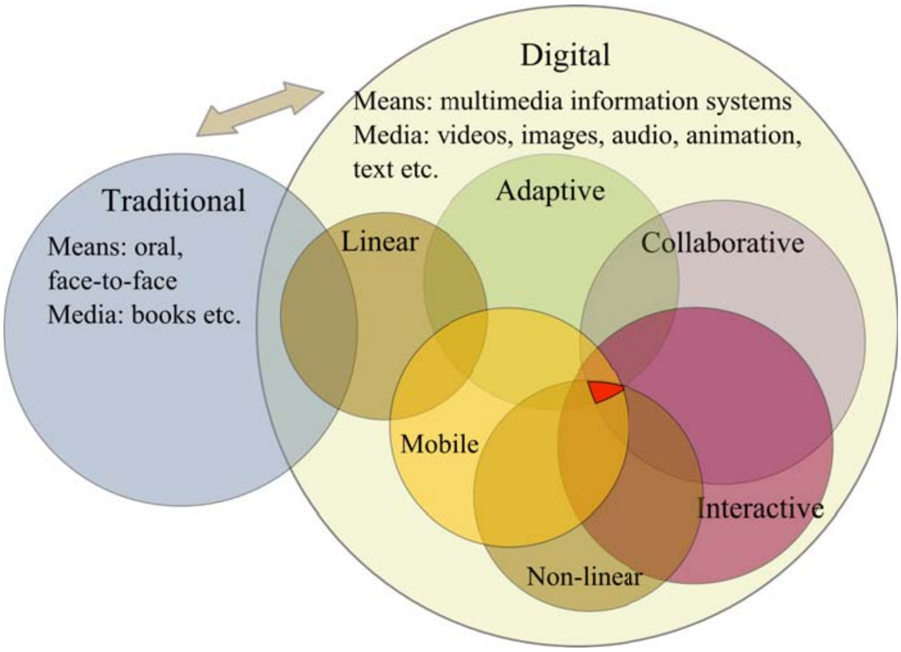

Figure 3.16: Storytelling approaches

literature survey, an abstract classification of the prevalent storytelling processes is depicted in Figure 3.16. The storytelling process may have different focuses on the conceptual level.

Linear vs. non-linear storytelling are differentiated based on action sequences of the media occurring in the story [CDAu10]. Non-linearity is introduced in order for storytellers to tell more complex stories with different storylines within a story. Different points of view on individual media could affect the normal flow of a story. Non-linear stories may be told in several versions with different content sequences [KCG*08]. Although the basic elements of a digital story are a narrative along with multimedia data, the generated story could be either linear, or non-linear. Linearity in a story would mean that the flow of the story follows simple rules and it has a certain beginning and a certain end. However, non-linearity is introduced in order to tell more complex stories. Different points of view could affect the normal flow of a story or conflicts interests could alternate parts of a story having as a result stories with nonlinear characteristics. The way, in which non-linearity is expressed, varies depending on the goal and the medium. For instance in movies flashbacks are the most usual means of non-linearity, while in case of digital stories, as a possible way of expressing non-linearity is the proposed Movement Oriented Design (MOD) technique [Shar05] .

Interactive storytelling, as an important research topic in the broader area of interactive digital entertainment, is mostly used at interactive fiction games. Dynamic narratives are created with which the user can interact. Users' decisions have an impact on story plot development, and the outcome is more personalized than the conventional linear storytelling, while different story beginnings and endings might happen. The story flow could follow a linear or a non-linear way of narration. The interactive storytelling process enables storytellers as well as story listeners to make their own decisions actively to determine the further course of the storyline [BaMu08]. Dynamic narratives are created with which users can interact at each part [MRS*08].

Adaptive storytelling gives storytellers the opportunity to interact with their audience through adaptive storytelling techniques. Some concepts of digital storytelling show that the narrative component is simultaneously decreasing with increasing interactivity. Adaptive digital storytelling techniques are used to encounter this problem [FrNi04].

The need for more personalized storytelling has led to the suggestion of many adaptive storytelling techniques. The level of adaptation depends on the goals and results of each proposed technique. Interactive storytelling provides adaptation on users' interests and stimulation in a highly rich multimedia environment. Other level adaptation are proposed based on social filters, such as the community interests which a user belongs to [CKMa08], or even location aware adaptation taking into advantage the mobility status of users.

Collaborative story creation is considered as an important approach to be applied in many e-learning systems for children and adolescence and it is useful for knowledge management.

Mobile storytelling takes place in a physical environment or situations where people actually move around and interact with digital content as well as with each other at a real world location using mobile devices and communication technologies [KCG*08, CHK*10]. The mobile storytelling approach can carry out tasks related to ubiquitous multimedia management well.

Storytelling can be applied on the three aspects of a Community of Practice:

(a) Mutual engagement: the storytelling process engages both storytellers and story listeners as two basic stereotypes. A role model can be derived to help the storytelling process.

(b) Joint enterprise: the storytelling process is based on a number of certain rules for multimedia organization. The underlying rules can be represented or realized in various story templates and their adaptation operations. The collaboratively created stories should match their underlying story templates accordingly.

(c) Shared repertoire: the storytelling process among community members can enrich resources in the shared repertoire of stories.

In fact, digital storytelling can only happen within communities of storytellers and the audience. Digital storytelling as a community activity is based on participation, not necessarily similar to classical storytelling approaches but more to a many-to-many approach. Storytelling in the Web 2.0 will depend on community strategies to maintain their media. Stories evolve over time, but even the disruption of stories by other users has to be dealt with by the communities in the Web 2.0. Multimedia and Web 2.0 technologies have to converge for storytelling on the Web 2.0. We need tagging technologies for retrieving interesting stories but we also need some kinds of emergent semantics for multimedia stories which are based on the content.

3.5 Handling Data Uncertainty

Although research on data uncertainty in advanced databases has made some progress, uncertainty handling on the community level is still at its early phase. This section pertains to the existing uncertainty progress in spatiotemporal and advanced uncertain databases. The role of communities in uncertainty handling is concluded as well.

3.5.1 Community-based Approaches to Information Overload

The information amount indexed by Google increases by the factor 56 from 2002 to 2009 which is far beyond the expected factor 16 according to Moore's law [Rang11]. As of January 2010, Twitter has announced 75 million registered users and Facebook 350 million[4]. If each user of Twitter and Facebook has just stored their registration data of 10 KB, a data volume of 4.25 terabyte is created. With this rapid explosion of information, benefits and impacts can be beyond any imagination. Mobile subscribers increase dramatically as well, with the increase of 17% cell phone users using the mobile Internet function in Germany and about 10 million mobile Internet users[5].

As the amount of data increases quickly, information overload has been addressed as an acute problem recently [BBCM10, STW*10]. Baez et al. [BBCM10] deal with the information overload problem with a set of approaches to maintaining and supporting the community, to modeling information dissemination and consumption, to sharing and providing feedback for information metrics, and to helping readers link their knowledge. They have implemented a so-called Liquid Journal model to realize the corresponding concept. Its core architecture consists of services on data, sharing, recommendation, subscription, and annotation. It summarizes the information processing steps. Liquid Journal stresses the roles of communities which confront the information overload and solve it via feedback and other community activities. It does not clarify how sharing, annotation, and subscription work together to facilitate scientific communities with information overload.

Simperl et al. [STW*10] have also started to conceptualize the mechanisms for creating, managing, and using information in enterprises. They focus on tagging, wikis, and ontologies for a better information sharing. Contextualized information delivery enhances the support of informal processes for knowledge workers.

[4] http://t3n.de/news/web-20-twitter-hat-75-mio-user-viele-ihnen-niemals-265852/

[5] http://www.heise.de/newsticker/meldung/Bitkom-Internet-per-Handy-erobert-den-Massenmarkt-1059179.html

Both projects observe the solutions to information overload or data uncertainty as a complex process beyond information technologies themselves. Users and communities are encouraged to be involved. Users' tagging, feedback, and recommendation influence and improve information sharing among users in communities. A systematic model and related operations are required to handle with this complex process, e.g. community-based storytelling. Storytelling is an efficient means to impart information and knowledge to user communities with high precision. Inconsistency and errors can be easily recognized during the storytelling process, as pointed out in Section 3.4.3 [BaMu08, Have07].

Stvilia et al. [SGT*04] put forward several uncertainty issues related to metadata based on an in-depth survey of the existing methodologies, concepts and techniques. First of all, usage contextual information is part of metadata. The same information may have different kinds and levels of quality and value in different contexts of use. For this relevance, relational or contextual information as a quality value is proposed to measure relationships between information and its usage context. Second, the intrinsic dimension refers to consistency and errors which are associated with and embedded in the metadata itself. Third, the reputational dimension focuses on resource provenance. In addition, metadata uncertainty handling is carried out in more than one level, e.g. macro and micro levels. The macro level refers to metadata schema and structure. The micro level refers to metadata component whether a single element is applied to describe information properly.

3.5.2 Spatiotemporal Uncertainty Modeling

As the uncertainty is often caused by resources of certain information, the domain of cultural heritage domain gives a good example. A great amount of temporal information has been retrieved from historical documents. These documents have a long history, so that the temporal information may be represented in different forms as in standard time expressions used nowadays.

The main spatiotemporal elements in information systems are event, cultural period, and location of an object etc. Event refers to all activities evolving cultural heritage objects. It includes the sub entities: fieldwork, conference, natural and social activities. Event is a spatiotemporal object having two sub classes, AREA and PERIOD, storing the information where and when the event happened. Cultural period is not a simple temporal object as its literal meaning. The cultural period is a spatiotemporal object class describing the period of a certain district. The "life span" of a site can be divided into several style periods.

The time instance type refers to the time points with the granularities from day to millenary. The time interval is frequently used in cultural heritage documentation. In the historical documents, the styles of findings have been denoted by using the names of historical periods. It has been proved that the materials and methods used to make the findings vary in the different phases due to the development of tools and techniques. The time period is generally represented as a time interval with the starting and end time points. In some cases, time interval data types could also be deployed to model the uncertain temporal data [DoYi98]. Hence, collection types are necessary for describing the events happened in a site or an area by using both point and interval types.

The temporal operators are required to manage the complex relationships of the temporal data. Allen [Alle83] discusses the temporal relationships based on interval data types. The possible relationships between two intervals may be denoted as *before, meets, overlaps, during, starts, finishes, equal*, and inverse relationships *inverse before, inverse meets, inverse overlaps, inverse during, inverse starts, inverse finishes*. These relationships determine the necessary operators for temporal data and can be extended to develop the uncertainty operators as in [DoYi98]. In latest temporal databases, temporal operators are designed to associate with the query design. And they should be used also for modeling spatiotemporal data.

Temporal queries and spatiotemporal queries are constructed based on the spatial and temporal data types, and predefined methods and operators as well. The common temporal query has three forms: simple temporal query, temporal range query, and temporal relationship query [LSAb02]. The simple temporal query asks the objects or events for a given time point. The temporal range query seeks what has happened in a time period. And the temporal relationship query inquires the objects related in time. Based on the spatial and temporal query, four spatiotemporal query types are further classified in [LSAb02]. The simple spatiotemporal query, spatiotemporal range query, and spatiotemporal relationship query have the similar definitions of temporal query types, and have been extended to the association with spatial query types. The spatiotemporal behavior query seeks the objects behaving differently in time and space, such as moving objects.

The query model designed for the new database should be able to proceed the simple, range, and relationship queries for temporal and spatiotemporal data. The functions of spatial and temporal data types support for modeling query and query languages. Therefore, the requirements of modeling queries should be considered at the phase of designing temporal data types. The aforementioned relationship operators can be deployed for the query model. The design of spatiotemporal query is associated with the predefined spatiotemporal objects. The functions and operators defined in a lower level, such as in the data types, can simplify the query language.

3.5.3 Advanced Uncertainty Databases

Traditional information systems are applied to process business data, which often consists of exact numbers. It is easier to make questions on numbers, because approximate or imprecise queries are not needed. Knowledge of the real world is almost always imperfect. In most cases, however, the data uncertainty problem has been recognized and paid attention in government, commercial and industrial environment. In research field, scientists have dealt with data uncertainty by means of mathematical methodology, probabilistic theory, and statistics which have been applied to handle sensor data and geospatial data. Geospatial data uncertainty has been handled with spatial data mining techniques [HeCh07].

The main data models are fuzzy logic-based models [BuPe82] and probabilistic models [LLRS97]. The general database models are based on a relational probabilistic data model in handling data uncertainty. Data mining techniques are widely used for data cleaning by defining error functions, for similarity search, and for mining streaming. Another close associated research area is data integration in which uncertainty is identified, some similarity matching rules are applied, and distances between uncertain objects are calculated.

Data uncertainty handling in relational databases are related to uncertainty modeling [Cui01, SBHW06] and uncertainty queries [Fuhr90]. In modeling and representing phases, the following example gives a tuple of the schema Talk (person, when, where, person). A certain record is:

[Anna, 12/23/2010, Oxford, Bill]

The following is an uncertain record: did Anna talk to Mark or Steve in Oxford on 12/23/2010?

[Anna, 12/23/2010, Oxford, Mark, Steve] ?

A formalized definition of *uncertain relation* is given in [SBHW06]: An uncertain relation R defines a set of possible instances, $I(R) = R_1, R_2, ..., R_n$, where each R_i is a relation instance. With the model, a set of reasonings takes place based on pre-defined rules. Sarma et al. [SBHW06] have noticed that low users' comprehension on the uncertainty model and further proposed a working model as a second-level representation on the data set with tuple-level confidence value. For example, Anna was 80% sure that she talked with Mark or Steve can be further represented as:

[Anna, 12/23/2010, Oxford, Mark(0.4), Steve(0.6)] 0.8

Thus, the possibility that Anna talked with Mark is 32% and can be further processed.

[Anna, 12/23/2010, Oxford, Mark] 0.32

This is implemented in Stanford Infolab Trio uncertain databases. The Trio project combines uncertainty with lineage based on long years' research on data uncertainty and data lineage. The data model behind is the uncertainty and lineage database (ULDB), which is a first implementation of both aspects [BSHW06, SBHW06]. The problems are that both information and its sources might be uncertain and inconsistent. Further solutions on database level are presented by monitoring all changes in databases to capture the data quality [DJMa06]. An uncertain relation represents a set of possible relation instances instead of a single one in traditional relational databases. Uncertainty query is performed on two levels. First, the membership check examines whether a result set belongs to the query results. Second, certainty check examines whether the result set equals to the query results.

The Orion database system, with its previous version U-DBMS, is an advanced uncertainty database management system developed at Purdue University. It is based on the probabilistic data model and employs PDFs. Orion defines relational operators and supports both attribute and tuple uncertainty with arbitrary correlations. It handles two categories of uncertainty problems: continuous and discrete uncertainty problems [SMM*08].

Data uncertainty is tightly related to the data quality issue which is a general problem in data management. A great amount of data is generated by user communities. In the real world, thus, data could be incomplete, imprecise, and even maliciously manipulated. Therefore, information quality is a crucial metric for the evaluation of information systems, together with the system quality metric. With the explosion of the information amount in the Internet nowadays, information quality issues are taken more and more into consideration in design, implementation, and maintenance of information systems. Accordingly, the cost of improvement of information quality rises all the time. Weinberger [Wein07] states that in knowledge management if there exists a possibility of uncertainty, it may be said that it is not a matter of knowledge. This uncertainty problem is increased, when many users are involved on Web 2.0. *Web uncertainty* refers to Web probability, Web fuzziness, Web randomness, etc. respectively [Zhan05]. These issues are even acute on Web 2.0.

In [BCFM09] a set of data quality dimensions are discussed with various information systems ranging from monolithic information systems, data warehouse, distributed information systems, cooperative information systems, Web Information Systems, to peer-to-peer information systems. However, no community information systems have been surveyed. Besides data-driven and process-driven requirement analysis, we handle requirements and process information in a community-driven or (user-driven) manner. All for good Web page, users' power is used.

At University of Washington new methods are developed for collecting social network structure and the shift in scale of these networks. The introduced degree of imprecision requires rethinking about how SNA techniques can be applied [AdRe07]. The research aims at providing tools to manage and manipulate imprecise or uncertain data. Probabilistic database technologies are applied here. The general problems are who would like to trust and apply such probabilistic data? Thus, the missing probability problem is also a powerful concept for uncertainty research [BGPo92].

Data uncertainty problems have been taken into consideration in some projects. GUEST developed at Yahoo! Research discovers social network sites such as Flickr, Delicious, and YouTube for trend searching [Yaho07]. GUEST attempts to leverage explicit and implicit social relationships for user personalized content discovery and performs tag analysis by detecting tagging patterns. Adar and Ré [AdRe07] point out that imprecision comes with applications like social network sites at a large scale. Developers cannot be confident that data about individuals or the connections between them are accurate. Probabilistic databases are claimed to be used, when the probabilistic rate is available. The only one purpose behind those applications is information sharing, whenever users update talking about daily location, experiences, or personal interests.

3.6 Summary

Data uncertainty handling is a main task for data management with the help of database management systems (DBMS). Moreover, uncertainty handling or reduction is not limited in database management systems with probabilistic and logic rule-based reasoning. The approaches in semantic web [DFHa03], context awareness [Gay09], community of practice [Weng98], and non-linear storytelling [Shar05] can be combined to reduce and manage mobile multimedia uncertainty.

A great amount of multimedia and complex user communities on mobile applications and Web 2.0 leads to data uncertainty problems, which is identified as *Uncertainty 2.0* in Chapter 2. Mobile context information makes data uncertainty problems in mobile information systems even more challenging.

Theories about information management establish a scope for the concepts developed in this dissertation from two aspects: media and communities of practices. They are two main columns building up mobile community information systems.

Media theories observe and handle the relations between media and its transcription (in forms of metadata) systematically. The derived media operations addressing, transcription, and localization are good starting points to take communities into consideration. Communities of practices are good and widely applicable as grounding stones for information system development. Practices are the core to make communities emerge and evolve.

Both theories make a playground and a theoretical basis for this dissertation. Although media theories have been proved in community information systems [Span07], the relations to mobile community information systems are still missing. Nevertheless, *Communities of practices* in the existing research is more a concept rather than being specified and realized. Thus, the realization of practices in CoP is focused on.

Besides the theoretical views, the Web 2.0 and mobile technologies and platforms are surveyed from practical viewpoints. Both mobile and Web 2.0 platforms result in uncertainty problems with regard to context, semantics, and communities. Moreover, a complete coverage of uncertainty problem on all three aspects on Web 2.0 and mobile platforms is albeit missing. Multimedia annotation and storytelling approaches as two important multimedia service categories are surveyed. They have the great potential to handle data uncertainty problems. However, the existing approaches and applications aim mainly at organizing multimedia content and not at uncertainty handling.

With regard to database technologies, the existing approaches to handling data uncertainty problems focus on probabilistic databases and data provenance management, which is useful for data management. However, the practical aspects have not been well covered.

The significant approaches to multimedia management include multimedia annotation and storytelling to create multimedia tags and story collections. However, it is suitable to apply them as they are in handling uncertainty 2.0 problems, because there have been few existing data models or methods systematically specified. On the other hand, uncertainty 2.0 problems need an integration of various aspects related to mobile and Web 2.0. Rich semantic information, complex contextual information, and community actions lead to uncertainty. Nevertheless, they provide a potential solution if they can be combined based on certain methods. The research gaps exist on the following aspects:

- Formulation of *Uncertainty 2.0*: uncertainty 2.0 is related to mobile and Web 2.0 platforms as defined in Chapter 2.
- Model-based specification of *Uncertainty 2.0*: uncertainty 2.0 dimensions and models are discussed in Chapter 4.
- Operation-based approaches to *Uncertainty 2.0*: the community-based multimedia storytelling approach is presented in Chapter 5.

In the pursuit of learning, every day something is acquired. In the pursuit of Tao, every day something is dropped.

Lao Tzu - Chapter 48

Chapter 4

Uncertainty 2.0 Modeling

So far, data uncertainty problems have been identified in mobile and Web 2.0 information systems. In this chapter, a data management model for uncertainty 2.0 handling is proposed. Web 2.0 and mobile platforms have great potential to help users reduce data uncertainty. The factors of community, experts, tags, semantics, context, and metadata intertwine to collaborate on information processing for web and mobile multimedia management. As identified in the survey of the state of the art in Chapter 3, there is little research on modeling and analysis of these various aspects.

A systematic information framework needs to be established for data uncertainty management with the benefits of different multimedia aspects and operations. First of all, the main conceptual handling model is introduced with five layers. Many approaches are developed on the layers of *context management*, *semantics management*, and *community of practice*. In this chapter, the realization framework of context management with technical details is discussed. Semantics management pertains to exploring the dimensions of user-generated tags. The interface between context management and community of practice is collaborative tagging approaches, which are analyzed and modeled with systematic methods.

4.1 Uncertainty 2.0 Handling Model for Mobile Multimedia Management

Based on context, multimedia semantics, and community approaches, an uncertainty 2.0 handling model is conceptualized to decompose the data uncertainty problem on different layers. Although the existing probabilistic approaches have made big progresses, a comprehensive modeling framework including multimedia and community aspects is required to deal with the complex data uncertainty problems.

The uncertainty 2.0 handling model is based on the aspects of mobile multimedia, metadata, context and semantics, and community, as depicted in Figure 4.1. Different approaches

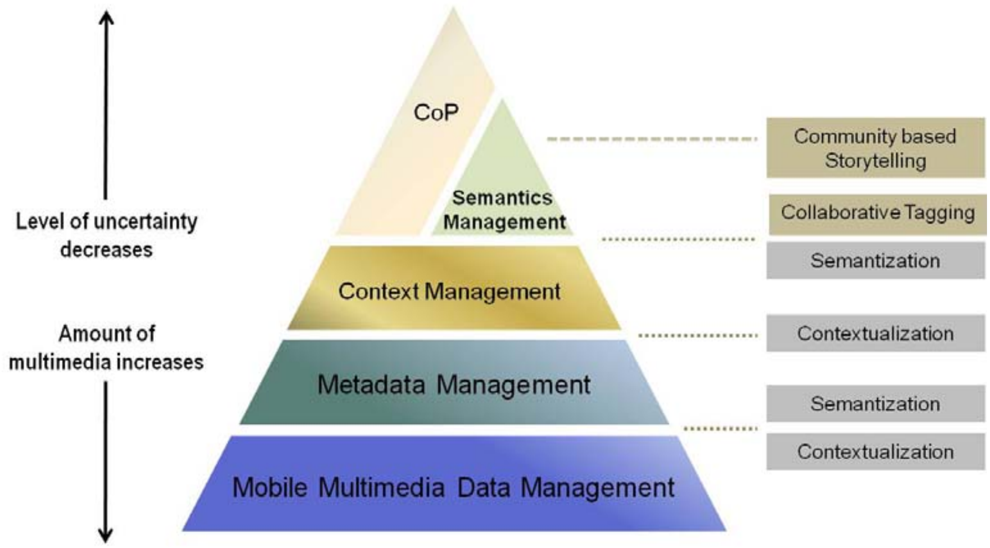

Figure 4.1: The uncertainty handling model for mobile multimedia management

related to each aspect are proposed with focus on the transition from the lower layers to the upper layers. Five layers are addressed in this model: Web and mobile multimedia management, metadata management related to Web 2.0 and mobile, context management, multimedia semantics management, and management of communities of practice.

On the lowest layer, the most mobile multimedia is scattered and managed by major Web 2.0 platforms and their mobile successors. The highest amount of mobile multimedia leads to the most data uncertainty (uncertainty 2.0). Level of uncertainty increases as the amount of multimedia gets bigger and bigger. If multimedia amount is considered as a main basis to attain knowledge, the multimedia handling process is a selection and deposit procedure of multimedia. Through handling efforts on different layers, the “right” multimedia is screened. Its uncertainty degree is decreased in line with the decrease of multimedia amount.

The main multimedia processing procedures are essentially multimedia contextualization and semantization which are in line with the media operations of transcription, localization, and addressing in the ATLAS media theory. On the upper layers, collaborative tagging for multimedia annotation and community-based digital storytelling for multimedia sharing take place. They intertwine and work together to handle uncertainty 2.0 in a spiral way. That means, contextualization and semantization take place one after the other at different levels, as depicted in Figure 4.2. Multimedia semantics has various representational forms via “metadata”, while context can contain diverse contextual information. Before the processing procedure, most context and semantics are of low-level. The semantization and contextualization processes are also seen as a transition procedure between multimedia semantics and context.

On the layer of mobile multimedia data management, media context and community con-

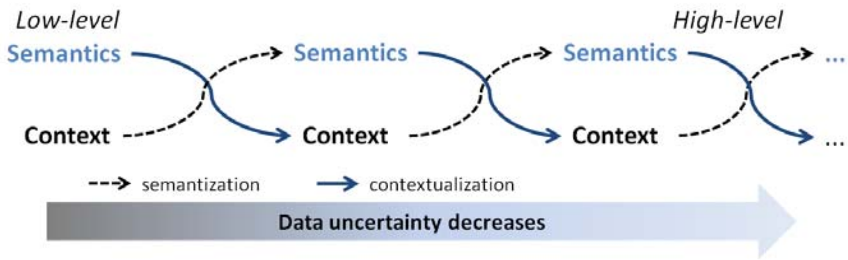

Figure 4.2: Spiral transformation between multimedia semantics and context

text capture represents the low-level contextualization procedure of a large amount of multimedia. In contrast to traditional digital multimedia management, *mobile multimedia management* highly depends on context [KSCa06a, AAKo06]. Context is all hidden and exposes facts about and around any object, including systems, users, communities, and society. Community context need be considered as well as multimedia context. This is useful to recognize communities on the Web 2.0.

On the layer of metadata management, multimedia is transcribed in various metadata standards. Although various types of context information are achieved and embedded in mobile multimedia, their metadata representation is not available automatically. Metadata enriches multimedia semantics and refines contextual information.

On the layer of context management, mapping models between context and multimedia semantic information are needed to reduce uncertainty. The context-semantic mapping models represent context in appropriate metadata standards. The semantic-context mapping models focus on the mappings from low-level semantics represented in metadata to context. Context management aims to improve the quality of context (QoC). Semantics consists of semantic rules as well, which can be used to reason out contextual information. At this step multimedia search results can be enriched with context-aware search and can be adapted to mobile devices.

On the layer of semantics management, different multimedia tags are managed. Tags have many dimensions covering semantics, context and community aspects. The conventional tag space of users, resources, and tags need be extended to communities. Consequently, the concept of *commsonomy* is proposed, which brings multimedia less uncertainty than folksonomy.

On the layer of community of practice, user communities are managed through a comprehensive user role model. Thus, amateurs have a playground to practice their skills to achieve more expertise knowledge. The more expertise knowledge that influences multimedia, the more uncertainty is reduced. Communities of practice cultivate experts from amateurs and reduce data uncertainty.

Considering the results of context management, practices can be carried out as an interface to community of practice. collaborative tagging for multimedia annotation transcribes multimedia artifacts into user-generated metadata as a high-level semantization process. The collaborative tagging approach benefits from the power of communities. Moreover, a context-aware semantic tagging model based on multimedia metadata standards is developed to support this multimedia annotation process.

Community-based digital storytelling transcribes multimedia into a collection of multimedia artifacts as a high-level contextualization procedure for multimedia sharing. Multimedia is used for certain context, e.g. problem solving or recommendation. At the same time, multimedia is addressed to certain (professional) communities. Research shows that the overwhelming majority of multimedia is located in the long tail [Ande06]. Only a small group of peers may consume a large amount of multimedia. Therefore, the contextualization task is to make those technologies developed for highly specialized communities of practice available on general purpose platforms like future versions of YouTube for example. Hence, community structures on the Web 2.0 and mobile are taken into consideration. Storytelling exploits community and multimedia to great extent for mobile multimedia management. Multimedia stories enhance readability of multimedia and reduce uncertainty.

In summary, uncertainty 2.0 which has a wide community basis is handled via the proposed approaches above. Furthermore, the multimedia management process builds up a workflow in a loop starting from mobile information capture, context information management (contextualization), semantic management (semantization), and collaborative semantization and contextualization via collaborative tagging and storytelling. Here, high-level semantization and contextualization processes are focused on. This process for mobile multimedia management is modeled in Figure 4.3.

Multimedia in persistent multimedia data storage is represented in metadata via semantization and contextualization. Multimedia metadata management carries out application and management of various multimedia even domain specific metadata standards. Multimedia tagging and annotation tasks can be carried out as a semantization process to generate metadata. Multimedia and its metadata can be contextualized to target different multimedia sharing purpose within or across communities. The efficient context management is able to adapt multimedia artifacts onto mobile platforms, targeting mobile communities via multimedia annotation and storytelling. The community-based storytelling approach is applied to reduce data uncertainty among communities, which enables media-community interactivity. The generated multimedia stories can be adapted to and consumed in mobile devices, as well as can enrich the mobile multimedia repository as an effective multimedia production means. Similarly, the adapted mobile multimedia stories produce additional multimedia content as well and circle the mobile multimedia management process.

4.2 Context Management

Context is a very broad concept discussed for more than forty years in computer science [SBGe99]. Generally speaking, much information processed in information systems can

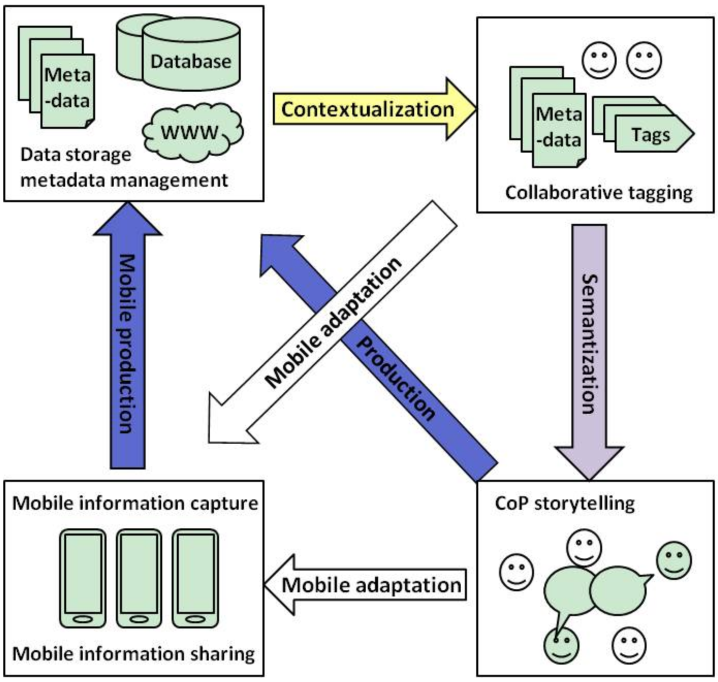

Figure 4.3: Workflow of mobile data management

be considered as context. Context uncertainty can be dealt with ontology-based context modeling. For recapulation, the basic definition on context is discussed in Chapter 3.

4.2.1 Multimedia Context

Based on mobile multimedia management *context* can be defined as information about a location, its environmental attributes, and people (including tasks, social roles, beliefs, and intentions), devices (including system capabilities and services offered), events, objects, and software agents that it contains [CDMF00a, CDMF00b, CPFJ04].

Context can be divided into low-level and high-level context. Low-level context is extracted from its environment directly and is not processed. It is a kind of "raw" information. As high-level context, community context awareness includes presence awareness [Prin99] and other information about community members [KSCa06a]. Users' online status shows and implements the presence awareness. Whether a multimedia file was reviewed by users shows the aspects of community awareness as well.

Mobile context-aware multimedia applications constantly sense the environment, change their behaviors due to changes in the context information, analyze, represent, and augment multimedia. Many mobile applications make use of these technologies, especially location-aware [VPKo04] and community-aware solutions [KSCa06b, MCCL06]. Because of the complicated behaviors of these applications and the needed investments in the infrastructures, even less multimedia is available for context-aware applications. There are even less multimedia involved, when the context-awareness includes the explicit management of the multimedia semantics [BDRo07].

Despite the fact that most of user-generated multimedia is produced with mobile devices, sharing and consumption of multimedia is still mostly using web-centered platforms. In some cases context information is lost, reduced or re-created using the Web 2.0 mechanisms like tagging or free-text annotations. Automatically generated metadata and even Web 2.0 metadata are seldom directly usable for context-aware applications.

The interaction between multimedia semantics and context can clarify uncertainty. Talk is an interactive means to deliver information which can be recorded, transcribed, digitized, and sent in pieces. On the other hand, listeners set information in a much lager context [BrDu00].

4.2.2 Ontology-based Context Modeling

As mentioned in the state of the art, context can be modeled by different approaches including key-value models, markup scheme models, graphical models, object-oriented models, logic-based models, and ontology-based models [StLi04]. Above all, the ontology-based context modeling approach is well evaluated for the purpose to describe context information clearly [CKHJ08]. Different from the approach in [LASo09], we use concepts specified in a certain ontology to represent context information. This context information includes spatial, temporal, community information and is presented in an ontology according to domain information.

Using OWL an ontology is described as a collection of RDF triples in the form of `(subject,predicate,object)`, in which `subject` and `object` are objects or individuals of an ontology and `predicate` is a property relation defined by the ontology.

Considering the uncertainty sources in Chapter 2, the RDF model depicted in Figure 4.4 can be applied to describe the Formula 1 race scenario instance. Multimedia information with its metadata presents the multimedia semantics such as creator, create_time, and tag. Context concerning community context includes the driver and team information in the lower part of Figure 4.4. The information about the Formula 1 Grand Prix gives multimedia context information as well. Uncertain information occurs in context at different levels spanning from location, time, devices, and community. A multimedia file delivers semantic information related to creation information and context information including the race place, the race round, and lap information of the race team.

For fixed geographical locations, e.g. race curves, pit stops, and tribunes, the ontology dimension `space` can be used. This ontology dimension is designed to support reasoning about the spatial relations between different locations, mapping from geo-spatial coordinates to the symbolic representation of space and vice versa [CPFJ04]. To specify the

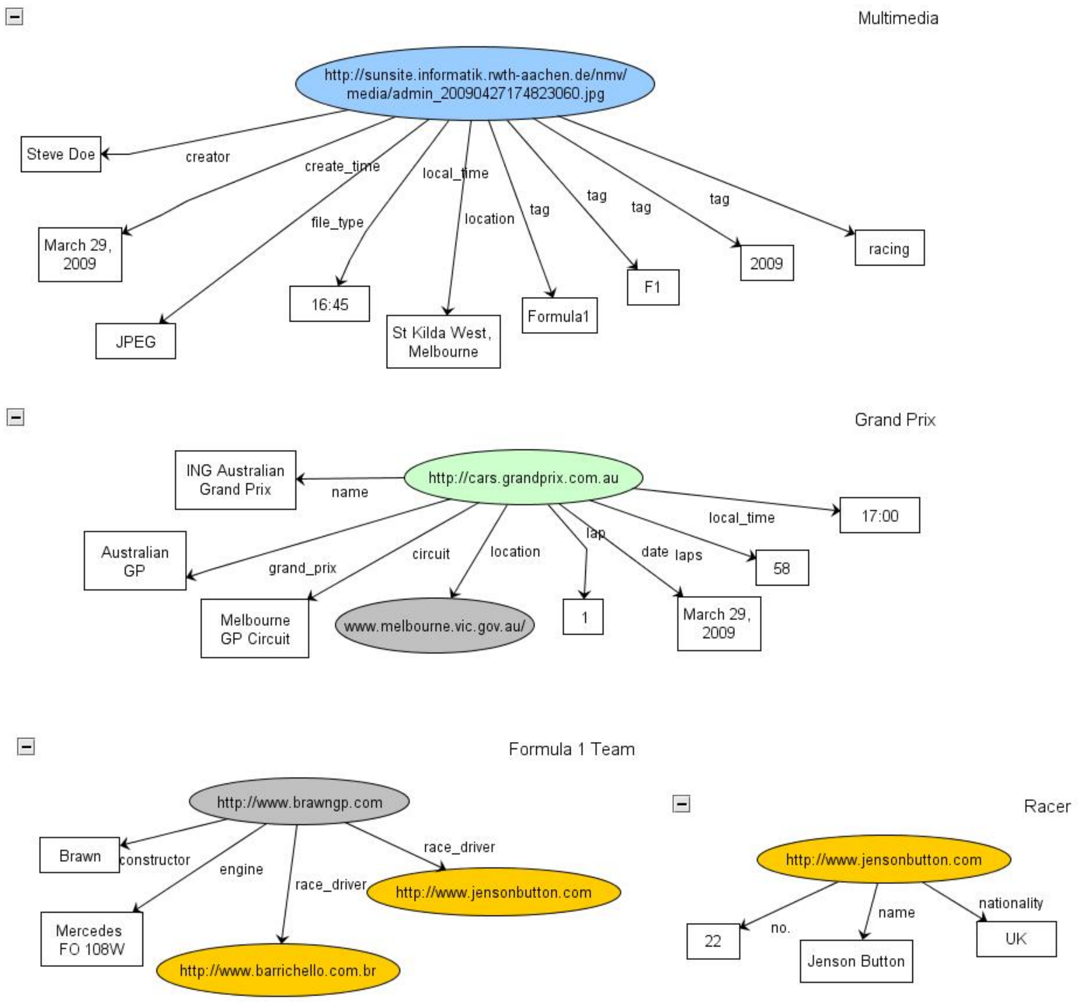

Figure 4.4: An RDF model for the Formula 1 race

geographical measurements of a location (e.g. the coordinates of a location), the ontology instance `geo-measurement` is specified in the ontology dimension `space`. And `geo-measurement` defines typical geo-spatial vocabularies of a space. They are used by the ontology dimension `space`.

The ontology dimension `person` defines the vocabularies to describe personal profiles as well as users' contact information. This ontology dimension has been developed based on the `soupa:Person` class in the SOUPA ontology. An instance (individual) of the class can be represented by a set of properties including name, age, gender, etc. of the person as well as his/her contact details including email, telephone number, mobile phone number, etc. In order to create a relation between the individuals of the class `space` and `person`, a new object property `locatedAt` is defined in the ontology dimension `person`.

The ontology dimension `time` describes temporal properties and temporal relations between different events. Part of the time ontology dimension adopts the vocabularies of time ontology dimension in SOUPA. The ontology dimension `time` includes mainly the class `TimeInstance` and `TimeInterval`, which represent a single time instance and the interval between two time instances respectively.

To make an association between temporal instance and date/time values in the `time` ontology dimension, three object properties are defined. A simple date type `xsd:dateTime` defined by XML Schema is used. The property `at` is defined for objects, e.g. events in association with a time instance (`TimeInstance`) and `xsd:dateTime`. Together with the ontology dimension `person`, personal movement can be traced as well. The properties `from` and `to` are defined to make an association between various instances of the class `TimeInterval`. So they define the temporal relation of two time properties which record the start and the end of an event.

The ontology dimension `community` models communities in terms of groups of people who have something in common. To clarify the concept of community in the previous scenario, we have developed a clustering algorithm to specify communities according to community members' interest [KSCa06a]. The instance of the community ontology dimension is updated, when a new user joins and when the new user's preferences are submitted. There are three key classes in the community ontology dimension. The class `community:Community`, which contains property `community:Name` and a number of instances of class `per:Person`. The object property `community:isMemberOf` specifies that a person is a member of a community. Through this property, the relation between ontology dimensions `Person` and `Community` is specified.

4.3 Semantics Management

An integration of context into multimedia semantics makes the contribution to enhance multimedia semantics. Context information is processed by (mobile) multimedia information systems. Semantics is derived from processed context information. Contextual information and multimedia are observed together for multimedia retrieval. But multimedia semantics and context are often researched separately in applied multimedia information systems for communities of practice. Often at the moments when we convert precise contextual information in human semantic knowledge representations we also lose already gained certainty again. Therefore, we need uncertainty management. While there is a lot of research about formal treatment of uncertainty on metadata and semantic knowledge representations we argue that the reduction of uncertainty is deeply rooted in the practice of communities of practice.

4.3.1 Multimedia Semantics

In Semantic Web *semantics* is specified as degree of both machine-readability and human-understandability. Semantics can be expressed in various formats, under which the clearest one is in text. Multimedia semantics is not clear but rich. The concept of *multimedia semantics* specifies rich semantics embedded in multimedia content. Images can contain much semantics, therefore, a different audience has a different interpretation of images.

Semantics can be categorized as low-level and high-level as well (cf. context). Machine readable content often represents low-level semantics [BHLa01]. Multimedia semantics can be extracted manually or automatically through media operations such as multimedia annotation in the community. Multimedia semantics is greatly part of high-level semantics, the information or message embedded in a graph or video is a complex. People can understand multimedia semantics better than machines.

Methods and approaches are needed to make multimedia semantics be processable. First of all, it is effective to employ metadata standards to represent multimedia semantics and to make it be processed easily. Second, context information is semantized to enhance multimedia semantics, which is discussed in Section 4.3.2.

Employment of metadata standards depends on domains. On the one hand, research fields like cultural heritage management and technology enhanced learning process a great amount of multimedia. On the other hand, multimedia semantics is crucial for knowledge management. Employment of metadata standards is explained below through an example in the domain of cultural heritage management.

A cultural heritage site in the physical world is documented with multimedia including photos and videos, etc. These multimedia files are collected by experts during some fieldwork. Semantics is associated with the domain and is embedded in multimedia as well. As mentioned in Chapter 3, metadata standards in cultural heritage management do not cover multimedia aspects very well. A crosswalk between multimedia metadata standards and cultural heritage metadata plays an important role to enhance multimedia semantics on cultural heritage. The model depicted in Figure 4.5 proposes a mapping model between the MPEG-7 metadata standard and information of cultural heritage sites. There is multimedia

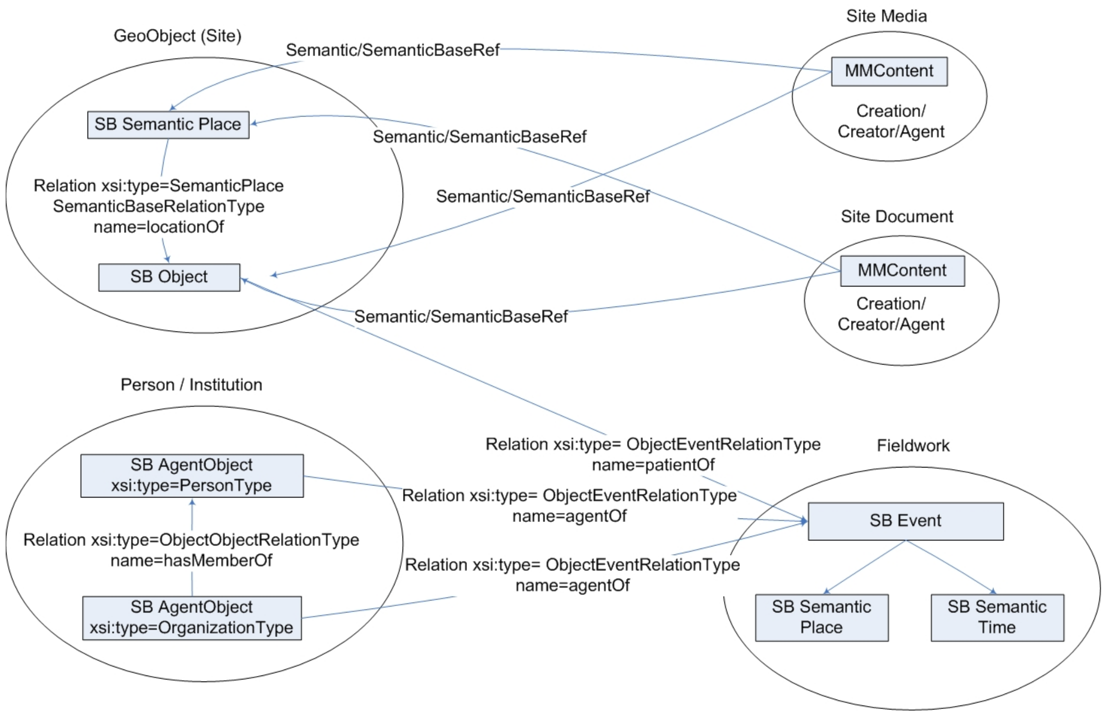

Figure 4.5: A metadata mapping model for cultural heritage management

information (*Site Media* and *Site Document*) for each cultural site (*GeoObject*) with location context information. *Fieldwork* as a cultural event takes place on site which has location and time information. Different semantic base (*SB*) types in the MPEG-7 standard are applied, so that the existing relationships among semantic base types can be established accordingly. Two common relationships are the converse pair *agentOf* and *patientOf* that specify which object operates on the other.

Use of this mapping model makes each piece of cultural information be associated to standardized metadata. This clarification procedure enhances semantics of cultural information.

4.3.2 Bridging Multimedia Semantics and Context

Either semantic information or context information alone can be erroneous. In the existing research on multimedia information systems, multimedia semantics and context are often observed and researched separately. Some of those multimedia information systems focus on multimedia adaptation and personalization, while some of them focus on context awareness.

In fact, both semantics and context have been processed together well. An example is the search engine on the Web like Google, which provides suggestions in the search input field. When a song title is typed, often *lyrics* is attached which indicates the context. A further approach to application of context information for multimedia adaptation in the

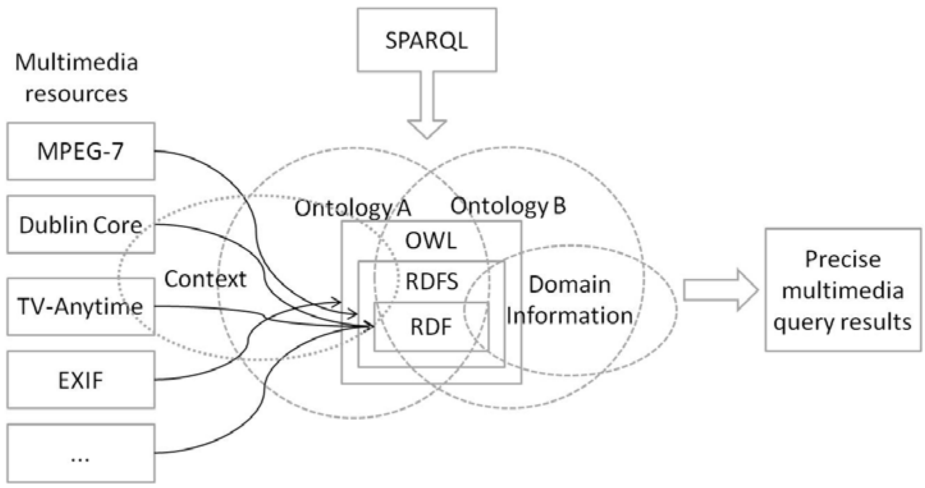

Figure 4.6: Multimedia semantics and context mapping for mobile adaptation

mobile environment is discussed in [KSCa06a]. This approach applies spatial, temporal, and community context to adapt multimedia in order to deliver multimedia results onto users' mobile devices. Le Grand et al. [LASo09] propose that contextual and semantic information is used together to enrich ontology in order to enhance information retrieval. They employ the concept of *context awareness* to express the relationships among different concepts to complete the ontology.

Thus, I propose a model to identify the information flow and to associate multimedia semantic and context information together, using ontology and impacts of communities of practices. This model can be further evaluated in mobile multimedia information systems which require context awareness and multimedia retrieval with higher relevance.

A model as depicted in Figure 4.6 is proposed to represent the usage of multimedia semantics and context information in order to enhance multimedia retrieval. This model is based on the analysis of the impacts of multimedia, metadata, domain information, context, and communities of practice.

Multimedia resources are described in industrial scale standards for the metadata description such as MPEG-7 [Kosc03], Dublin Core [Glad07a], TV-anytime [PfSr00, ETSI05], and EXIF, etc. On the metadata level, RDF, RDFS as well as OWL are proposed as Semantic Web technologies. Resource Description Framework (RDF) [BeMc04] provides data model specifications and XML-based serialization syntax. RDF Schema (RDFS) specifies RDF to simplify the process of using Web Ontology Language OWL [BHH*04] and also enables the definition of domain ontologies and sharing of domain vocabularies [WZGP04]. OWL can be used for the following purposes: (1) *domain formalization*, a domain can be formalized by defining classes and properties of those classes; (2) *property definition*, individuals and assert properties about classes can be defined; (3) *reasoning*, one can reason about these classes and individuals. Thus, RDF together with RDFS and OWL can represent context with the

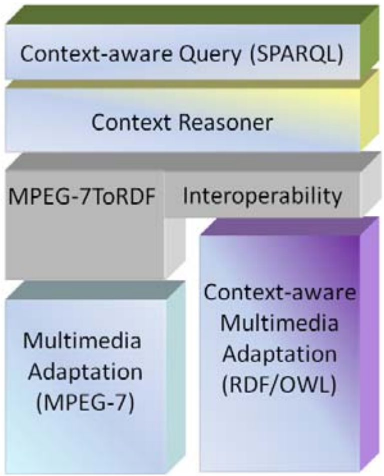

Figure 4.7: Context management for mobile multimedia adaptation

information from a certain domain or communities of practice. The SPARQL Protocol and RDF Query Language (SPARQL) can be used for context reasoning [SPARQL07] .

An ontology is often needed to convert context information into multimedia semantics. The benefit to use ontology models is to avoid the complexity of mapping among different multimedia metadata standards. The goal is to enrich multimedia semantics with enhanced multimedia interoperability among different multimedia formats and diverse multimedia metadata standards. Ontology is represented by a series of concepts which are tightly related to certain domain knowledge.

With the help of an ontology-based context model using OWL/RDF and the substantially enhanced interoperability, context information can be expressed and reasoned with community information systems. In summary, the reasoning with SPARQL is carried out on the data set of semantics, context even knowledge or information from communities. The goal is to use multiple dimensions of information and community users' practices to identify, analyze, and reduce the possible information errors.

Considering the realization of mobile context-aware community information systems, a realization framework for mobile multimedia adaptation with context management is proposed in Figure 4.7. The framework is concerned with mobile multimedia semantics, with multimedia metadata, with context management, with ontology models, and with multimedia uncertainty management.

The two main columns are components for *multimedia adaptation* and *context-aware multimedia adaptation*. More precisely, they are based on multimedia metadata for multimedia semantics and a comprehensive ontology-based context model respectively. A converter from multimedia semantics described in the MPEG-7 standard to ontology in RDF formats bridges the gap between both columns. Based on the both main columns, tasks for context reasoning and multimedia uncertainty management can be carried out. A mobile multimedia testbed on the ground serves as a monitoring component to trace multimedia data flow and multimedia application calls.

As an example, Listing 1 describes a curve's location in the aforementioned Formula One race scenario. This location information is represented as the semantic base type *Place* in the MPEG-7 multimedia metadata standard.

```
<urn:Mpeg7 xmlns="urn:mpeg:mpeg7:schema:2004"
xmlns:urn="urn:mpeg:mpeg7:schema:2004"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" >
 <urn:DescriptionMetadata id="doc_166701246674134">
  <urn:LastUpdate>2009-04-27T18:11:02:138F1000+01:00</urn:LastUpdate>
  <urn:CreationTime>2009-04-27T18:11:02:138F1000+01:00</urn:CreationTime>
  <urn:Instrument>
   <urn:Tool><urn:Name>LAS MPEG-7 Services v1.0</urn:Name></urn:Tool>
  </urn:Instrument>
 </urn:DescriptionMetadata>
 <urn:Description xsi:type="urn:SemanticDescriptionType"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <urn:Semantics>
   <urn:Label />
   <urn:SemanticBase xsi:type="urn:SemanticPlaceType"
    id="SemanticPlaceType_admin20090427181102149">
    <urn:Label>
     <urn:Name>curve 7</urn:Name>
     <urn:Definition> australia grand prix route</urn:Definition>
    </urn:Label>
    <urn:Place>
     <urn:GeographicPosition>
      <urn:Point altitude="34.0" latitude="-37.83931" longitude="144.969449" />
     </urn:GeographicPosition>
    </urn:Place>
   </urn:SemanticBase>
  </urn:Semantics>
 </urn:Description>
</urn:Mpeg7>
```

Listing 1: An MPEG-7 file for description of SemanticBaseType Place

A service of a converter from MPEG-7 to RDF is designed and realized to meet users' requirements. The binding of MPEG-7 and Semantic Web encoded in RDF is one of the basic components beside the service. The contribution of this converter realization is mainly in two aspects. One is the adapted converting service which enables the MPEG-7 multimedia standards to be understandable. This is an extension of the existing research by the Rhizomik Initiative. The converter consists of transformation from RDF to HTML, XML Schema to OWL, and XML to RDF. An ontology schema based on a mapping of MPEG-7 schema to RDF is additionally specified.

MPEG-7 Schema is mapped to ontology before MPEG-7 documents are transformed into RDF. For the context-aware query processing, two steps are carried out sequentially. Firstly, all queries related to context information are expressed and evaluated in XQuery. Second, SPARQL queries are prepared for executing on RDF documents, after the converter has processed the metadata documents.

Using the semantic-context converter *MPEG-7ToRDF*, an MPEG-7 description of a *SemanticBaseType Place* (cf. Listing 1) is transformed into an RDF file with related semantic information in Listing 2.

```
<rdf:RDF
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:mpeg7="http://manet.informatik.rwth-aachen.de/~khodaei/mpeg7-v2.owl#">
  <rdf:Description rdf:about="http://manet.informatik.rwth-aachen.de/~kovachev/xml/
  curve1.xml">
    <mpeg7:Description>
      <mpeg7:SemanticDescriptionType>
        <mpeg7:Semantics rdf:parseType="Resource">
          <mpeg7:SemanticBase>
            <mpeg7:SemanticPlaceType rdf:about="http://manet.informatik.rwth-aachen.de/
            ~kovachev/xml/curve1.xml#SemanticPlaceType_admin20090427181102149">
              <mpeg7:Place rdf:parseType="Resource">
                <mpeg7:GeographicPosition rdf:parseType="Resource">
                  <mpeg7:Point rdf:parseType="Resource">
                    <mpeg7:longitude>144.969449</mpeg7:longitude>
                    <mpeg7:latitude>-37.83931</mpeg7:latitude>
                    <mpeg7:altitude>29.0</mpeg7:altitude>
                  </mpeg7:Point>
                </mpeg7:GeographicPosition>
              </mpeg7:Place>
              <mpeg7:Label rdf:parseType="Resource">
               <mpeg7:Definition>australia grand prix route</mpeg7:Definition>
                <mpeg7:Name>curve 7</mpeg7:Name>
              </mpeg7:Label>
            </mpeg7:SemanticPlaceType>
          </mpeg7:SemanticBase>
          <mpeg7:Label rdf:parseType="Resource"></mpeg7:Label>
        </mpeg7:Semantics>
        <rdf:value rdf:resource="http://manet.informatik.rwth-aachen.de/~khodaei/
        mpeg7-v2.owl#CompleteDescriptionType"/>
      </mpeg7:SemanticDescriptionType>
    </mpeg7:Description>
    <mpeg7:DescriptionMetadata>
      <rdf:Description rdf:about="http://manet.informatik.rwth-aachen.de/~kovachev/
           xml/curve1.xml#doc_166701246674134">
        <mpeg7:Instrument rdf:parseType="Resource">
          <mpeg7:Tool rdf:parseType="Resource">
            <mpeg7:Name>LAS MPEG-7 Services v1.0</mpeg7:Name>
            <rdf:value rdf:resource="http://manet.informatik.rwth-aachen.de/~khodaei/
                 mpeg7-v2.owl#TermUseType"/>
          </mpeg7:Tool>
          <rdf:value rdf:resource="http://manet.informatik.rwth-aachen.de/~khodaei/
               mpeg7-v2.owl#CreationToolType"/>
        </mpeg7:Instrument>
        <mpeg7:CreationTime>2009-04-27T18:11:02:138F1000+01:00</mpeg7:CreationTime>
        <mpeg7:LastUpdate>2009-04-27T18:11:02:138F1000+01:00</mpeg7:LastUpdate>
        <rdf:value rdf:resource="http://manet.informatik.rwth-aachen.de/~khodaei/
             mpeg7-v2.owl#DescriptionMetadataType"/>
      </rdf:Description>
    </mpeg7:DescriptionMetadata>
  </rdf:Description>
</rdf:RDF>
```

Listing 2: RDF file instance after the conversion

The converter is adapted and realized for the latest MPEG-7 Schema of 2004. The MPEG-7 to RDF converter works within two packages, XSD2OWL and XML2RDF. XSD2OWL facilitates the transformation of MPEG-7 Schema into MPEG-7 Ontology, while XML2RDF transforms XML based MPEG-7 documents into RDF formats.

At the next step, the *context-aware multimedia adaptation* service enables multimedia search based on keywords specified by users and users' context across the RDF files. It uses the Web Service technologies in order to provide easy access to mobile applications on the client side. On the server side, a set of services provide functionality such as context acquisition, context reasoning, and context querying. On the client side, mobile user interfaces can process users' requests and retrieve demanding multimedia results. Listing 3 gives an example of a SPARQL query on RDF files to search for Formula One racers close to a race curve.

```
PREFIX mpeg7: <http://manet.informatik.rwth-aachen.de/~khodaei/mpeg7-v2.owl#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
SELECT ?agent ?place
WHERE {
 ?agent mpeg7:name "FirstName LastName"
 ?agent mpeg7:hasGeographicPosition ?loc1
 ?loc1 mpeg7:longitude ?lon1
 ?loc1 mpeg7:latitude ?lat1
 ?place mpeg7:hasGeographicPosition ?loc2
      ?place mpeg7:definition "curve 7"
 ?loc2 mpeg7:longitude ?lon2
 ?loc2 mpeg7:latitude ?lat2
 FILTER Distance(?loc1, ?loc2) <= distance
}
```

Listing 3: An example of a SPARQL query on RDF files

Another SPARQL query in Listing 4 searches for all photos taken at a certain curve of a certain race.

```
PREFIX mpeg7: <http://manet.informatik.rwth-aachen.de/~khodaei/mpeg7-v2.owl#>
                        PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
                        PREFIX xsd:   <http://www.w3.org/2001/XMLSchema#>
                        PREFIX fn:  <http://www.w3.org/2005/xpath-functions#>
                        SELECT  ?l ?alt ?file
                        WHERE { ?l mpeg7:Place ?r .
                                   ?r mpeg7:GeographicPosition ?r2 .
                                   ?r2 mpeg7:Point ?r3 .
                                   ?r3 mpeg7:altitude ?alt .
                                   ?l mpeg7:Label ?label .
                                   ?label mpeg7:Name "curve 7" .
                                   ?l ?spt mpeg7:SemanticPlaceType .
                                   ?mc1 mpeg7:SemanticBaseRef ?ll .
                                   ?des mpeg7:Semantic ?mc1 .
                                   ?des mpeg7:MediaInformation ?mi .
                                   ?mi mpeg7:MediaIdentification ?mid .
                                   ?mid mpeg7:EntityIdentifier ?file .
                        FILTER (xsd:float(?alt) > 23.0).
                            FILTER (STR(?l) = ?ll) }
```

Listing 4: The SPARQL query for Formula One multimedia search

Thus, Semantic Web technologies are applied for context-aware queries in order to deliver users multimedia search results with basic context reasoning, e.g. the distance between a person and a place.

4.3.3 Metadata and Dimensions of Tags

Beyonds the mapping to context, user generated tags play the role of metadata to semantize multimedia in handling uncertainty 2.0 problems. Lynch [Lync60] (pp. 69 ff.) points out that locations have certain boundaries, while some boundaries may be soft or uncertain. Thus, the related edges between those locations play a secondary role. Strong edges lead to disorganization to a few people. In this sense, tagging works. People need more time to handle rapidly increasing amount of information, especially multimedia. Tags give multimedia data comprehensive descriptions. Thus, tags and their dimensions are decided to be powerful metadata types.

Tags convey thematic information of multimedia data, a concept derived from GIS. Tags are high-dimensional data, and can represent multi-category information. Tags are used as a prevalent metadata nowadays. Tags embed much information to measure mobile multimedia uncertainty. Tagging activities could be associated with motivations, sufficiency, miscellaneous and uncertainty, and centrality. Ontology focuses on classification and certainty.

When a user is confronted with uncertain multimedia, a measure system is needed to tell how uncertain this data is. Users have to analyze the degree of data uncertainty via a set of uncertainty measures in different dimensions. Therefore, the dimensions of tags are summarized in Figure 4.8 based on existing platforms with tagging functions. They are located in the space of users, tags, and resources. Additionally, these dimensions are related to the three aspects semantics, context, and community as listed in Table 4.1.

- *Cross-media:* It refers to degree of resource content, whether different formats of multimedia are embedded as tags.
- *Cross-platform:* Tags can belong to or be applicable for only one platform, or many platforms. Tags can be merged from one platform into another.
- *Language:* Tag language depends not only on resource language but also on users' preferable language.
- *Location:* They are geographic coordinates and other location-related tags.
- *Time:* It is temporal contextual information.
- *Domain:* Resources have certain domain information and domain-specific tags.

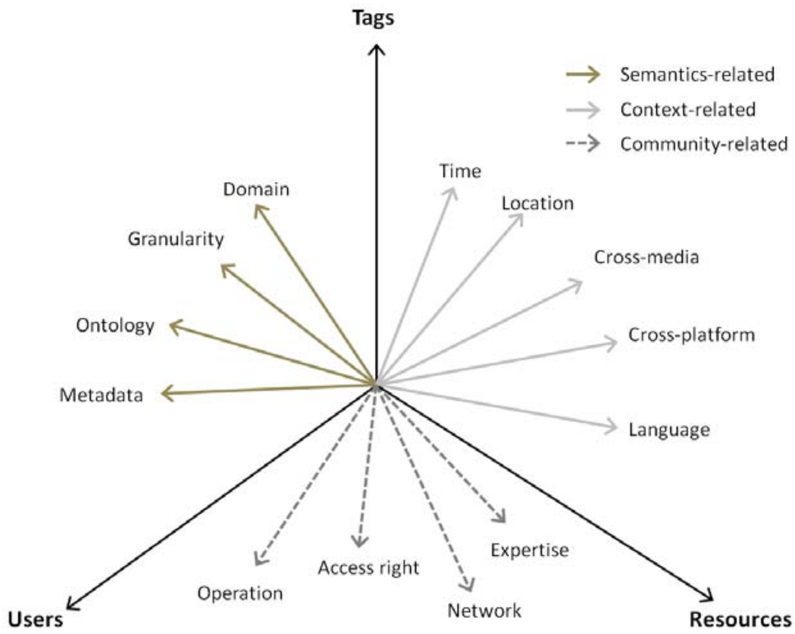

Figure 4.8: The dimensional tag space

- *Granularity:* Tags can be applied for a certain object within a multimedia item or the complete multimedia to improve the precision of tags.
- *Metadata:* Tags can be either *free text* or well *structured* based on certain metadata standards. Metadata enriches multimedia semantics.
- *Ontology:* In semantic web, ontology is defined and applied. On the Web 2.0, folksonomy is built up. Folksonomy can be seen as another type of ontology. It is formed in a bottom-up way instead of the predefined conventional ontology.
- *Access right:* Rights range from *public* to *private*. Whether a tag belongs to public or private categories is decided by users and related to the access rights of the resources.
- *Expertise:* Expertise of users can be linked with domains or multimedia, ranging from *amateurs* to *experts*. A domain expert could be a multimedia amateur.
- *Network:* It refers to social networks. Tags can belong to certain user networks or user communities.
- *Operation:* This dimension defines the operational aspects of tags. A tag can be a rate value as well.

Table 4.1 shows that there are few existing tagging platforms with regard to the community aspect. In addition, these various aspects widen the usage scope of tags. Besides the

	Dimensions	Web 2.0 tagging platforms as examples	Uncertainty examples
Context	Cross-media	Facebook	Different media formats
	Cross-platform	FriendFeed	Tags used in different platforms
	Language	Amazon	Special symbols in multiple languages
	Location	Flickr, Facebook	Wrong location information
	Time	Flickr, Facebook	Wrong time information
Semantics	Domains	CiteULike	Tags used in different domains
	Granularity	M-OntoMat-Annotizer, Flickr	Unclear object region
	Metadata	IBM VideoAnnEx	Different metadata standards with similar vocabulary
	Ontology	M-OntoMat-Annotizer	Inappropriate ontology selection
Community	Access right	Delicious	Wrong assignment of access and tagging rights
	Expertise	Last.fm	Authority
	Network	Facebook, Last.fm	Assigment of people to a wrong social network
	Operation	Google+	Selection of various community operations

Table 4.1: A comparison of data uncertainty with regard to tag dimensions

examples given above, there are other interpretations to observe these tag dimensions. For example, a rating of an online product is also a tag given by users who have bought this product. It has the dimensions of metadata standards, e.g. the scale and specification for rating information, as well as domain. Tags about usage information are collected to increase data quality. Missing values can be computed and filled in.

4.4 Community Tagging and Commsonomy

Content description has proved to be an effective way to label or annotate multimedia information [SKLu07]. Two approaches are often used to annotate multimedia. One is the Web 2.0 prevalent tagging in free text. The other is adding meta information in line with certain multimedia metadata standards.

The triangle consisting of *resource*, *tag*, and *user* is the prevalent Web 2.0 tagging model. In the contrast, conventional information systems and community of practice focus on resource, user and community for knowledge management. I integrate community into the Web 2.0

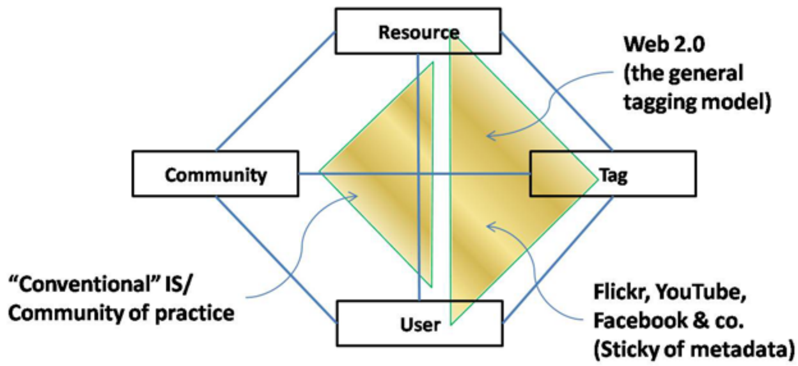

Figure 4.9: Community-based Web 2.0 tagging model

tagging model as depicted in Figure 4.9. Communities have also shaped the following concept *commsonomy* instead of the general folksonomy.

Furthermore, various Web 2.0 operations are summarized and analyzed as approaches to semantics and context uncertainty management for Web 2.0 resources.

4.4.1 Concept of Commsonomy and Web 2.0 Operations

Commsonomy is community-based folksonomy defined and used within and across communities of practice [KSRe07]. Folksonomy comes into being as a kind of wide-spread taxonomy with unlimited concepts created by users on social network sites. Commsonomy is considered as a subset of folksonomy with certain community impacts. Concepts or labels in use are limited to certain community contexts. Commsonomy supplements the background knowledge with four main elements including user, resource, tag, and community as depicted in Figure 4.9.

Tagging is a process to give a label or many labels to a media item. It has its advantage to map information into as many categories as possible. However, this leads to certain complexity if the multimedia content has many categories. For example, there is a smart division of elements, acts, scenes, lines, speeches, and characters in the theater piece of Hamlet or Dante. Tags can be added to each division. Thus, multimedia annotation with various tags at various levels leads to user generated uncertainty as well.

Furthermore, various Web 2.0 operations can be considered as a variant of the tagging activity, as mentioned before. Tagging as a super concept for community operations, users' rating and ranking activities belong to a sub group of tags. They give community context information to multimedia. Both in mobile or laptop platforms, there are a set of community multimedia operations with high complexity. Let me take a Web page at New York Times as an example. Except the "conventional" operations such as e-mail and print, readers can send the link to mobile phones, and use the most prevalent social network services such as recommending at Facebook and broadcasting at Twitter. The "share" button includes

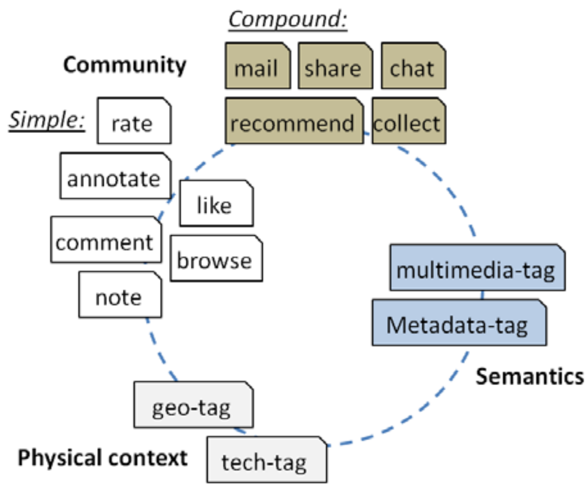

Figure 4.10: Web 2.0 operations on web resources

another 6 services, e.g. LinkedIn and MySpace. Resources are collected in a cross-platform way. It is different from the way that we shared media in the past. Several years ago, we added the link into our personal favorite bookmark collections or sent it to our friends via emails, when we were interested in a web resource. Last but not least, sometimes we could subscribe to its newsletters. In addition, we ranked a product or travel agent available online. We also rated comments in some BBS forums. Nowadays, a web resource can be marked with various methods. A set of Web 2.0 operations are summarized in Figure 4.10. All these user activities are operations on context and semantic information.

At a first glance, all these activities make Web resources link with themselves more tightly. Social aggregation even leads to poor data quality. Duplicate RSS entries appear often. If the community aspect is applied, an order can be founded on the Web 2.0 as stated in Chapter 3. The community aspect of data uncertainty is introduced by users' ambiguous media operations. Data uncertainty can be reduced through simplifying community media operations.

Given a community or a platform as (U, op, M, T, C) where U is a set of users; op is the operation; M is a set of media; T is a set of tags; and C is the community platform. This notation specifies the general idea to formalize different Web 2.0 operations. More details are given in Section 4.4.2.

The listed operations in Figure 4.10 can be further modeled with the aforementioned commsonomy model. Figure 4.11 illustrates the information flow among user, tag, resource and community. Users can *like*, *annotate*, *comment*, or *rate* resources. The term *annotate* is used for the usual Web 2.0 tagging activities (*tag*), in order to make the activity *tag* distinguished from the label *tag*. The difference between the action *like* and the action *rate* is that rate has an additional tag information to specify its quality. Stars are often given or a scale "1-5" or even "1-10" is given. The rate result can be optionally forwarded to other

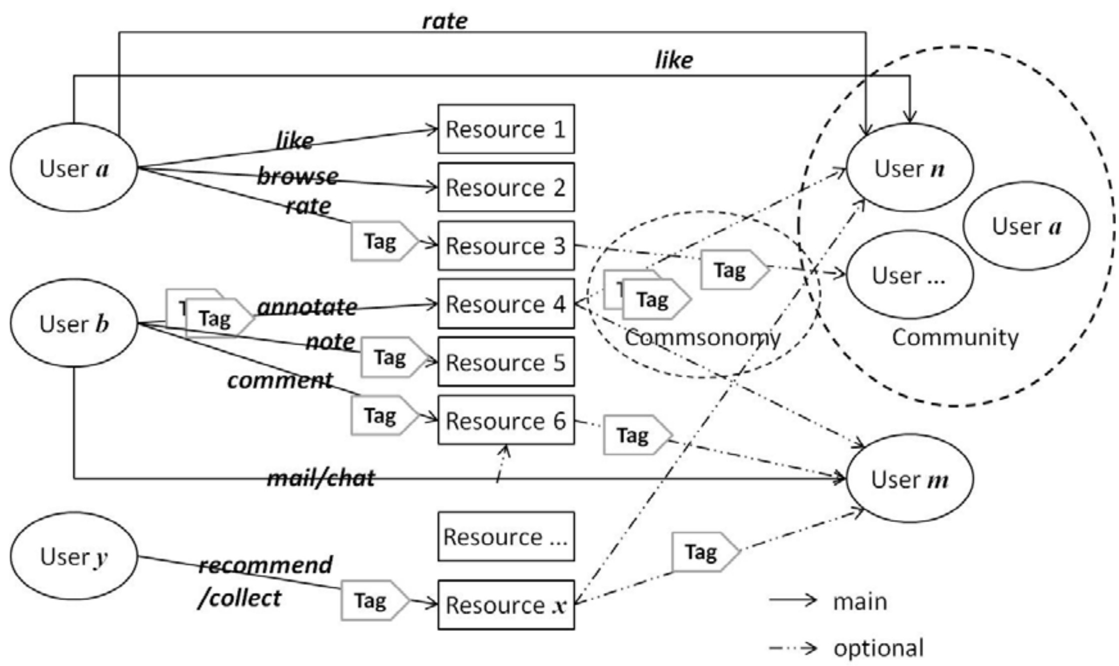

Figure 4.11: Web 2.0 operations based on the commsonomy model

users, so that those users share this rating. A user may like a resource, and he/she may like the other users. In this sense, a group or friend list is created. Like another user can be seen as a simple operation to make the others one's social network. Rating another user can be carried out by grouping one's individual contacts within one's network.

4.4.2 Modeling Web 2.0 Operations

Operations can be grouped in the following categories according to their usage or the number of parameters which is discussed as operation features:

Usage groups: *Semantic operations* give certain tags to media artifacts as a transcription operation. Tags are a set of $T = (t_1, t_2, ..., t_n)$. Semantic operations use tags as a basis. The operation *annotate* is to transcribe a media item with a set of tags: $(u_i, anno, m_j, T, c_k)$. The operation *comment* can be represented in $(u_i, comment, m_j, T, c_k)$ where $T = (t_1, t_2, ..., t_n)$.

Context operations give certain context-related tags to media and localize multimedia artifacts. A schema is predefined to describe what kind of context is listed and in use. The value is given to an entity. For example, geo-tagging is a location context operation on media $(u_i, anno, m_j, (T_{context}, t_n), c_k))$. This holds also for the operation *rate*. The operation *rate* reflects the community context exactly. The operation *rate* is defined with $(u_i, rate, m_j, T_{context}, c_n)$ where $T_{context}$ is a value from the rate scalar.

Community operations localize media to user communities including *like*, *share*, *recommend*, or add into (*collect*) a collection. These operations target a community of users. The data privacy degree is decided by the size of the community. Generally, three groups can be identified: private, semi-public or group, community-wide or public. If the user oneself is targeted, the media is well reserved for one's own use. If a group of people is targeted, the media is shared within a certain group. The symbol "@ -(at)" is often in use to target other users. Thus, the access rights are well managed in this way.

- Like is specified as $(u_i, like, m_j, t, c_k)$ where $t \in \{0, 1\}$.
- Share is also called forward in some social network sites: $(u_i, share, m_j, T_{context}, c_n)$, where $c_n \subset c_k$.
- Recommend is specified as $((u_i, recommend, m_l, T_{context}, c_n)$, where $c_n \subset c_k$ or c_n consists of one user u_j.
- Collect/add is a combined operation of annotation and like $(u_i, collect, m_j, T_{context}, c_n \subset c_k)$

Parameter groups:

I differentiate operations of *unary* and *multiple*, according to the number of the elements in the tag set. *Unary operations* identify the relationship between a media item and a user with one value in the tag set. The community information is still in the background. A typical unary operation is *like*, as *like* in Facebook is often embedded in a large number of web resources. *Multiple operations* have more subsets as parameters with tag sets, such as the operations annotate, comment, and recommend.

Furthermore, operations are specified as *simple* and *compound*, according to the selection conditions of tag values. If free text or unary operations are applied, the operations are simple. If the tag value has certain restrictions such as geographical coordinates or a value from a rating scalar, the operations are compound.

This formulation of various operations among different platforms contribute to solve the community uncertainty problem mentioned in Section 2.2.4. To summarize, Table 4.2 gives an overview about all operations with examples on Web 2.0 and mobile platforms. From the up-to-date most prevalent social network sites, Facebook, YouTube, Last.fm, Flickr, Twitter, Delicious are selected for the comparison. Facebook is a typical successful example of social aggregation, while the other platforms are based on media sharing of different formats including videos, audios, images, texts, and links.

In summary, each user-generated additional piece of information on other web resources may be seen as a tag on Web 2.0 and mobile devices. Tagging is a complex operation related to context, semantics, and communities. Hence, a data model is generated to specify the comprehensive operations between users and media, to identify the links between users, media, and tags across diverse communities.

-	Operations	Tag set elements	Notation	Examples
Simple	Like	Unary	$(u_i, like, m_j, t, c_n)$ where $t \in \{0, 1\}$	Facebook, YouTube, Flickr
	Annotate	Multiple	$(u_i, anno, m_j, T, c_n)$	Delicious, Flickr
	Comment/note	Multiple	$(u_i, comment/note, m_j, T, c_n)$ where $T = (t_1, t_2, ..., t_n)$	Facebook, Delicious
Compound	Geo-tagging	Multiple	$(u_i, anno, m_j, (T_{context}, t_n), c_n)$	Facebook, Flickr
	Chat/mail	Multiple	$(u_i, chat/mail, m_j, (T_{context}, t_n), c_n)$	Facebook, Twitter, YouTube
	Rate	Multiple	$(u_i, rate, m_j, T_{context}, c_n)$ where $T_{context} \in ratescalarvalue$	Facebook, Amazon, Ebay
	Share/recommend	Multiple	$(u_i, share/rec, m_j, T_{context}, c_n)$	Google Reader, Google+, Twitter, YouTube, Amazon

Table 4.2: Web 2.0 media operations

The overview model proposed in Figure 4.9 can be extended into a complete model with Web 2.0 operations as depicted in Figure 4.12. Various operations can be unified as tagging. The activities like, comment, rating, and so on belong to the tag category. They put forward multimedia metadata. Web resources also include multimedia stories which are explained in the next chapter. Users and communities may have various subtypes as well.

4.5 Related Work on Tagging Platforms

After my tagging approach is proposed in Section 4.4, I make a comparison between my approaches and the existing tagging platforms. The existing tagging platforms based on metadata standards and the Web 2.0 are surveyed. The comparison is conducted between Web 2.0 tagging platforms and the tagging approaches within our solution Virtual Campfire.

4.5.1 Existing Metadata-based Annotation Platforms

Much research work on metadata has been carried out to develop annotation systems. Several selective platforms are discussed as follows:

Semantic Video Annotation Suite[1] is developed at the Joanneum Research Institute and is a desktop-based application. It fully supports the MPEG-7 standard and provides automatic annotation support such as object recognition and object tracking. The user interface is complex and needs a steep learning curve.

IBM VideoAnnEx Annotation Tool[2] provides MPEG-7 based semantic video annotation. In

[1] http://www.joanneum.at/fb2/iis/produkte-loesungen-services/semantic-video-annotation.html
[2] http://www.research.ibm.com/VideoAnnEx/

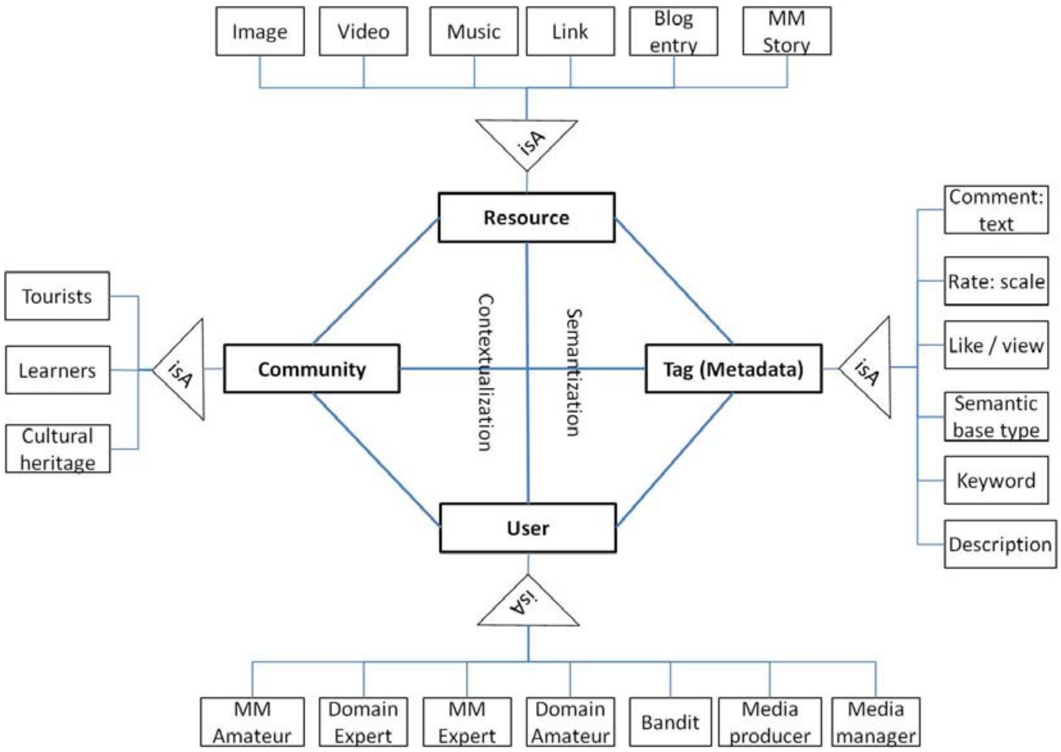

Figure 4.12: A complete community-based Web 2.0 tagging model

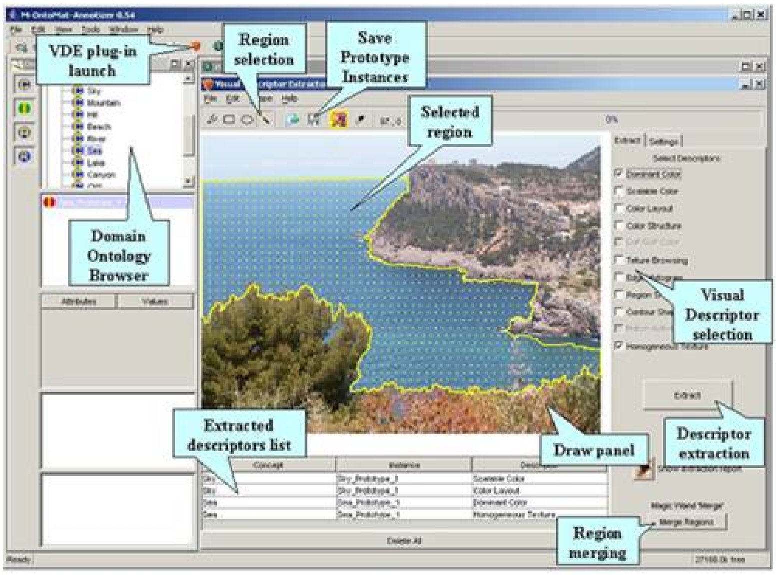

Figure 4.13: Screenshot of M-OntoMat-Annotizer

addition to using the MPEG-7 semantic base types, this tool allows the user to create one's own library of semantic base types flexibly. However, the user interface is quite complex.

M-OntoMat-Annotizer developed by aceMedia allows MPEG-7 based video and image annotations (see Figure 4.13). An additional feature is the automatic region recognition, which divides every video frame into smaller elements. It has the most complex user interface of all presented tools [BPS*05].

VideoANT[3] by the University of Minnesota can be used for text annotations. Like YouTube, it is a web-based service, which allows annotating flash videos (see Figure 4.14). Adding an annotation requires only one click and is convenient to use. All annotations are listed on the right side of the video and can be accessed all the time.

The design of multimedia annotation user interface is an issue related to uncertainty handling as well. Comparing intuitive and precise tools, they differ strongly in the user interface. VideoANT has only a few buttons and users can add and delete annotations quickly. Precise tools tend to overload their user interface with a lot of buttons and possibilities. The non-professional users feel uncomfortable and overwhelmed, when they look at these tools. Therefore, the user interface should be very clearly structured and hide more complex annotation functionality from normal users.

These existing video semantization systems still have many problems. Most of them are developed for rather generic use than for a special application domain. Another problem related to the aforementioned generality is the complexity of terminology. Different communities cultivate terminologies on different levels of complexity. In that sense, semi-professionals

[3]http://ant.umn.edu

Figure 4.14: Screenshot of VideoANT

do not share the same terminology as professionals and should thus be supported for instance by a thesaurus. Furthermore, complicated features based on professional user requirements lead to poor usability of these platforms. Our Virtual Campfire solution has differentiated user communities and has offered different tagging approaches to be adapted to user communities ranging from amateurs to experts communities. Since users are supported by adaptive tagging approaches, the solution interface is easily usable. The prototype is called SeViAnno with more technical details in Chapter 6.

4.5.2 Existing Web 2.0 Annotation Platforms

Different tagging approaches can be demonstrated and analyzed in the selected existing social network sites (SNS). The dimensions of tag structures in these platforms are explored. Tags are applied widely for information management. There is a clear media separation among different platforms. Audio/music, videos, or photos are handled in different ways. Table 4.3 gives an overview of these platforms.

Delicious[4] was founded in 2003 as one of the earliest social bookmarking services employing tags. When a user tags a web resource, time information is recorded with the tags together. Popularity of a tag is recorded and computed automatically. Users are also supported to send a resource to other users or the other platforms. Correspondingly, resources can be explored by time, popularity, and network later. Resource lists consist of the recent or fresh lists, the hot lists, and the lists based on certain tags. Tags are suggested based on both

[4]www.delicious.com

users' personal tag collections and all users' popular tags. But they are not identified later, i.e. whether a tag comes from one's personal collection or the crowd source can be not identified later.

Flickr[5] is a social network site started in 2004 and employs tags for photos shared on a wide user community. Contextual information including photo shooting time and location is often extracted from the technical metadata. Persons and other concepts on photos are differentiated. Users can even specify people directly within a rectangle region on photos. Besides tagging, comments can be added as well. Except photo exploration based on places, time, and certain common interests, photos are identified as *interesting* by random. The view frequency might be recorded but is not one important statistics. There are no general tags suggested due to the versatileness of images.

Last.fm[6] is a social network site for music sharing. Tagging activities in Last.fm are featured with expert tags, since music has a well defined taxonomy. There is a detailed categorization of semantic information. For example, persons can be categorized as singers, composers, interpreter, DJs, and so on. Music can be searched and retrieved according to similar artists and top-listening according to expert tags and the view statistics. Users' personal collections are well supported.

YouTube[7] is a social network site for video sharing with tagging support. Upload date is added while location information needs to be added explicitly by users. The tag function is extended to add comments or hyperlinks, or even advertisements. Annotations during watching the video can be easily attached with no more than two clicks. Nevertheless, only free text annotation can be added. Video search and retrieval are not supported by annotations. The view statistic of a video is of highly importance during random video exploration and search.

This comparison shows that the Virtual Campfire SeViAnno prototype with combined tagging approaches considers and implements nearly all functions.

[5] www.flickr.com
[6] www.last.fm
[7] www.youtube.com

SNS			Delicious	Flickr	Last.fm	YouTube	VC: SeViAnno
Resource media			links	photos	music	videos	photos & videos
Tag dimensions	Context	Time	upload	capture / upload	- /artist related	upload	points/ intervals
		Location	-	place	artist related	- /place	map-based
	Semantics	Metadata	-	people	artists, music style	people	*agent* role
		Granularity	-	region-based people tag	-	bulbs	multi-granular
	Community	Access right	private / public	private / public	private / public	public	community
		Network	networks	contacts	role-based (DJs)	friends	community
		Expert	no	no	yes	no	yes
User activities	Operations	Within community	note	description, like, comment	like, comment	like, comment	annotate
		Cross-platform	@twitter	share	share	share	shared repertoire
	Exploration	Popularity	people bookmarked	view statistics	listen statistics	view statistics	CoP self-monitoring
		Organization	tag bundle	set, stream	play list	play list	user-specified
		Others	time-based	context-based	semantic-based	general search	semantic-based

Table 4.3: A survey of existing social network sites (SNS) with tagging

Storytelling is the most powerful way to put ideas into the world today.

Robert McKee

Chapter 5

Community Approaches to Handling Uncertainty 2.0

As stressed in Chapter 4, tagging is an efficient means to manage and organize multimedia semantics and context. Storytelling is a powerful tool for community-based or personal multimedia management. Multimedia becomes more expressive via storytelling. Storytelling can be applied for decision making, for strategy making, for business, and for academic reports. Storytelling is an effective media operation where semantics, context, and communities need to work together.

Community-based storytelling is an integrated multimedia processing approach to uncertainty handling in mobile community information systems. First of all, multimedia metadata, semantics and context management discussed in Chapter 4 are baselines for multimedia storytelling. The storytelling aspects may have many facets. In this chapter, requirements engineering and storytelling scenario design are discussed first. Based on them, story modeling, story media authoring and story design using story templates are further proposed. Community aspects are discussed with community user role design and management.

5.1 Multimedia Storytelling

The most precious resource in a computer system is no longer its processor, memory, disk, or network, but rather human attention[1]. When a story is told, people give the storyteller a couple of moments of their attention. It's important for storytellers to keep this attention. Thus, when storytellers tell a story, they are consuming an important and scare resource, human attention. This attention can be used for knowledge management and mobile data management; for the latter several application scenarios are illustrated.

[1]Project Aura@Carnegie Mellon University: http://www-2.cs.cmu.edu/ãura/

5.1.1 Storytelling for Knowledge Management

Storytelling is one of the oldest communication means to connect communities via media. People love telling stories, because stories are compact and easy to be memorized and shared. To tell a story can involve emotion and visual impact. These stories are not only for kids at bed time, but they are indistinguishable forms of multimedia. Stories include personal views, emotions, storylines, heroes and heroines, sequences, and other elements.

Haven [Have07] defines the power and effectiveness of stories with three main components: specific informational elements, the core structure of stories, and the informational demands of human neural story maps. Specific information elements can be multimedia content. The core architecture is associated with story templates.

In my dissertation, storytelling is a compound media operation with multiple tag values. The resulted multimedia stories consist of a sequence of selective multimedia artifacts shared and recommended in communities. Figure 5.1 shows how a multimedia story looks like. This story about the Battleship "G. Averof" is created by the project partners according to some historic documents.

> The Battle of Elli (also known as the Naval Battle of the Dardanelles) took place on 16 December [O.S. 3 December] 1912 as part of the First Balkan War[2]. The Royal Hellenic Navy, led by Rear Admiral Pavlos Kountouriotis on board the flagship Averof, defeated the Ottoman Navy, just outside the entrance to the Dardanelles (Hellespont). During the battle, Kountouriotis, frustrated by the slow speed of the three older Greek battleships Hydra, Spetsai and Psara, hoisted the Flag Signal for the letter Z which stood for "Independent Action", and sailed forward alone at a speed of 20 knots, against the Turkish fleet. Taking full advantage in her superior speed, guns and armour, Averof succeeded in crossing the Turkish fleet's "T" and concentrated her fire against the Ottoman flagship Barbaros Hayreddin, thus forcing the Ottoman fleet to retreat in disorder. The Greek fleet, including the destroyers Aetos, Ierax and Panthir continued to pursue the Turkish fleet off-and-on between the dates of December 13 and December 26, 1912. This victory was quite significant in that the Turkish navy retreated within the Straits and left the Aegean Sea to the+ Greeks who were now free to liberate the islands of Lesbos, Chios, Lemnos and Samos.

Some main story elements in summary include:

- Title: The naval battle of Ellis
- Hero: Rear-Admiral and Commander-in-Chief of the fleet of the Aegean Pavlos Kountouriotis (1855-1935)

[2] source: http://en.wikipedia.org/wiki/Naval_Battle_of_Elli

- Date: 3 December 1912
- Location: off the Dardanelles
- Framework: Balkan Wars 1912-1913

The researchers who are working on the Battleship "G. Averof" multimedia documents often deal with different historic documents. Thus, sometimes it is hard to tell a consistent story, while stories may have different foci targeting different story listeners. Thus, they apply the community-based storytelling with certain story templates which are explained in detail in Section 5.2.3. Figure 5.1 illustrates a storyline tree. The nodes denote *begin*, *middle*, and *end* of a story. Each node can connect to another story sub tree or multimedia documents. Finally, the dash lines with arrows show the media sequences in a story. In this story, only images are in use, although it is possible to attach videos or text documents as well. Hence, it is possible to use the same multimedia artifacts and tell a story in different sequences. For example, the story ends in this situation according to the diary which is a combination of the diaries of S. Dousmanis (captain of "G. Averof") and A.Sakellariou (political officer), offered by Georgios Kritikis, a historian at Harokopio University in Athens:

> ... 300700: We are behind of the Tenedos's channel. /1100: We turn to Limnos island. /1725: Anchor at Moudro. 310730: Coal loading.

Thus, the map of Limnos island can be used instead of the other big map. This story is created to depict and deepen the knowledge on that war in the history for communities of practice. It can be used at history classes in schools. The students may also interact the storylines by adding other connecting lines to edit the media sequences or by changing the multimedia artifacts.

In this sense, storytelling is to circulate information and performs information management in an open loop with enhanced data quality. Therefore, storytelling is an effective approach to knowledge management. If we human take knowledge sharing as a goal, multimedia is the "serialized" form of this knowledge, and storytelling is a "deserializing" process. In knowledge management, if there exists a possibility of uncertainty, it is not a matter of knowledge [Wein07]. To stress the role of knowledge management, the storytelling platforms surveyed in Chapter 3 can be compared according to the existing knowledge processing models. Davenport [Dave05] distinguishes knowledge-intensive processes in four models according to level of interdependence and the complexity of work. He defines interdependence between individual actors and collaborative groups, while he specifies the complexity of work between routine work and interpretation judgment. Table 5.1 summarizes the knowledge models related to different storytelling approaches and the existing platforms introduced at the end of Chapter 5.

Nowadays storytelling has been empowered by rich multimedia experiences, in comparison to mono audio, reading books, and face-to-face experience imparting. Storytelling is an

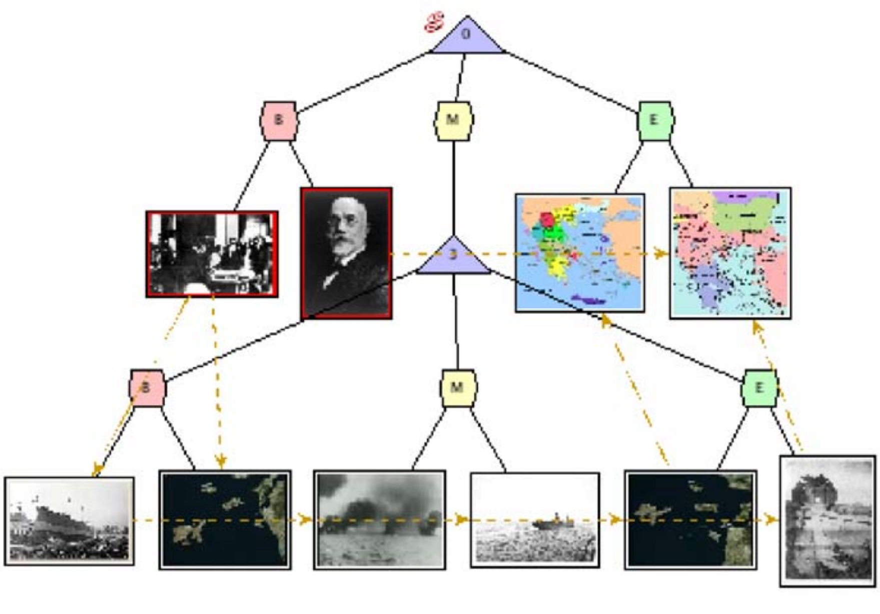

Figure 5.1: An example of a story for the Battleship "Averof"

important communication means among friends, families, news reporters, and audiences. It is embedded in human nature, but only new technologies will probably change the ways stories are told. The ultimate technology is when you plug in yourself in the brain, and you get all information, as shown in the film *Matrix*. The Internet and mobile devices offer many possibilities for users to share knowledge and experiences in an effective and interesting way in the virtual world, coexisting to the real world. From CNN Hero program to YouTube, storytelling has been applied to journalism, tourism, and learning processes. Storytellers establish an implicit contract with the audience that creates trust, such that both parties get what they came for [Broo03].

Multimedia storytelling opens a new way to extend face-to-face storytelling into the virtual world with low communication barriers, as Haven [Have07] noted: "The discussion about why a story is important takes place not around a table in an interior room but in public pages accessed through links on the front page that lead to comments left by dozens and sometimes hundreds of readers who talk with one another about the story's accuracy, importance, and meaning."

As multimedia tagging approaches are discussed in Chapter 4, tags and tagging activities have a wider application area than giving keywords. Commenting, rating, and sharing as Web 2.0 media operations can be all represented by a corresponding tag type. All these tags can be considered on the same level of description. Any media operation identifies one piece of media or a small collection of media. Tagging approaches decompose media. In contrast, storytelling approaches compose various pieces of multimedia into a series of multimedia collections with certain storylines. Practices taking place in communities can

	Features	Storytelling approaches	Examples
Transaction model	routine work by individuals	single images, audio slides or videos	TV, films, BBC Telling Lives
Integration model	routine work by collaborative groups	social tagging for multimedia	Flickr, YouTube, Inscape [GBFe05], Alice [KePa07], MIST [SKSJ06]
Collaboration model	interpretation/judgment work by collaborative groups	collaborative multimedia authoring	Dramatica [PhHu01], MovieLens, YouTell
Expert model	interpretation/judgment work by individuals	role models, expert finding	YouTell [CKMa08], Art-scene [ZaMa04]

Table 5.1: Storytelling in knowledge-intensive processes

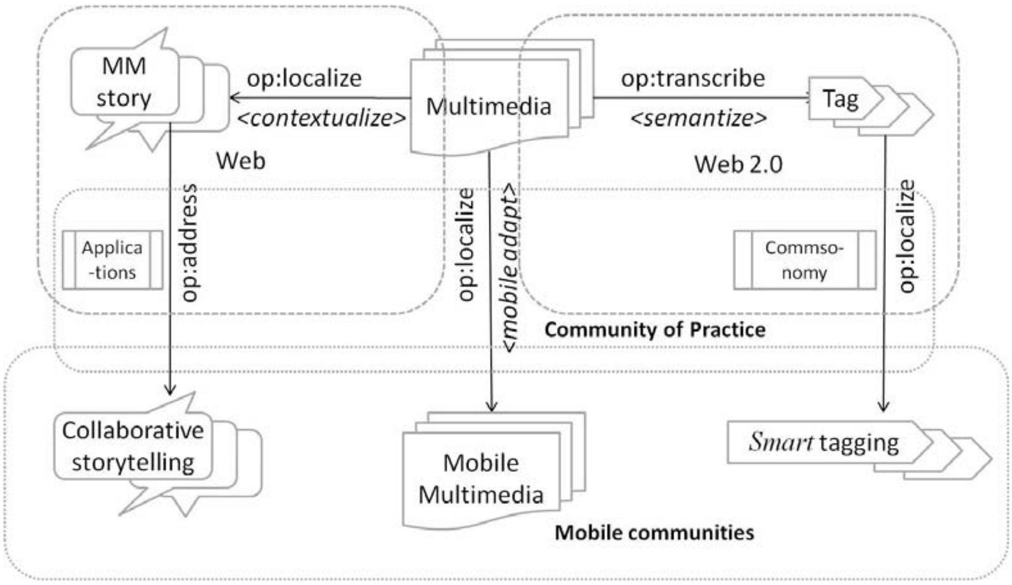

Figure 5.2: Media flow and operations on media by storytelling and tagging

help communities build up and evolve. However, Web 2.0 lacks community-based operations or practices. Storytelling is an important practice for communities as a complement.

Based on the given operations of semantization and contextualization, the storytelling process is a multimedia contextualization process. The storytelling operation can be seen as a new aggregated operation on multimedia across user communities. Figure 5.2 shows how the storytelling approach executes the function of media operations on web and mobile multimedia. The media operations addressing, transcription, and localization [Jaeg02, Span07, Klam10] are well integrated in the Web 2.0 and mobile media flow diagram.

The flow from multimedia to its tags including comments, ratings, etc. is essential on the Web 2.0. A lot of derivatives can be created. Web 2.0 model is a derivative data model. Multimedia makes stories. All multimedia tags are auxiliary to make up a story as well.

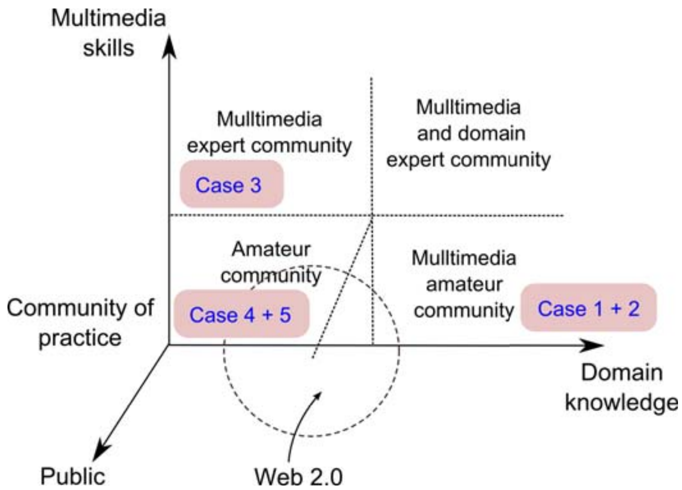

Figure 5.3: Case studies targeting different communities on community of practice and Web 2.0

Similar to the tagging operations, community-based storytelling takes place on Web 2.0 along with the Web 2.0 media operations, in regard to practices based on the *community of practice* concept.

5.1.2 Scenarios and Requirements on Multimedia Storytelling

From the community's point of view, it is important to grasp the user communities' requirements on multimedia storytelling. We have conducted a requirement analysis based on professional user communities as well as multimedia amateur communities.

Multimedia amateur communities are identified as communities which are professional in their domains or disciplines but amateurish in the management of mobile multimedia. They produce and consume a large amount of multimedia with other community members. But they do not have professional experiences in processing and managing the multimedia collections.

Several use cases can demonstrate the requirements and usage of multimedia storytelling for amateur communities according to domain knowledge and multimedia skills as depicted in Figure 5.3. The axis "public" shows whether the community is close/private, community-based or public. Web 2.0 is identified as having public media accessibility. These professional communities are often not public but communities of practices.

Case 1: Intergenerational knowledge transfer. Since 2003 we have worked on cultural heritage management for Afghanistan together with experts from the Faculty of Architecture at RWTH Aachen University. They travel frequently to Bamiyan Valley in Afghanistan and report the severe preservation problems there. On the one hand, in the years of the civil war and under the Taliban regime many monuments and sites have been damaged and vandalized. A lot of still existing art, antiques, and other cultural objects are in danger of thieves and illegal trades. Much on-site guarding and surveying work has been carried out. All this relief work need be documented with multimedia.

On the other hand, the cultural heritage management in Afghanistan were interrupted, even worsened due to the wars from 1980s. Although some information collected before has been preserved and kept in archives by the pre-war generation of researchers, most of it is scattered all around the world and badly organized. It is very important to protect the information on cultural heritage from unsafe access, while a global access is guaranteed [KSJ*06a]. The generational research gap makes it urgent for researchers or local preservation workers to approach the experts of the prior generation rather than face-to-face knowledge imparting (see Figure 5.4 left).

Case 1 addresses requirements on storytelling especially in *security* and *reliability* aspects. Only experts and restricted users are authorized to be storytellers and story listeners to create and share the multimedia stories for cultural heritage management in Afghanistan.

Case 2: Vocational method training. Mobile devices and technical equipment are employed on site for cultural heritage management relief work, which has raised many research challenges within the UMIC Virtual Campfire project [CKJa10]. Template-based storytelling explains how a certain device or a complicated technical equipment can be operated or set up. Quick, easy, and cheap acquisition and processing methods for multimedia are required at cultural heritage sites due to limited available resources for documentation activities. Further device functionalities such as GPS and other digital documentation tools are also applied. Automation of documentation processes such as automated extraction of measurement data including 3D data is realized by using low-cost standard video documentation hardware or even advanced mobile phone cameras. Thus, computational efforts focus on creating meaningful semantically enriched information from extracted 3D information and incorporated into new 3D environment for storytelling.

Remote sensing data via high-resolution satellites is supported by airborne drones and used to identify cultural site information in remote areas. These technologies become increasingly important in urban and regional planning processes. We use the survey results from large heritage areas acquired by programmable un-manned helicopters equipped with video camera systems (so-called tiny helicopter cameras) and GPS receivers [KTC*09, CKJa10]. This data collected on site with enhanced ubiquity is combined with satellite data from other sources. And this data is incorporated into complex and collaborative planning processes for urban or regional planners. The location especially the city walls of Ghazni has been surveyed with advanced video cameras and devices. A group of experts at this mission need to master device techniques in order to create and share better multimedia experiences.

Case 2 raises requirements on storytelling with regard to *rapid data transmission* and *mobility*. When experts learn how to use devices via multimedia stories, these stories have to be transferred to communities at real time wherever the experts are working.

Case 3: On-site knowledge practicing. This case is technically similar to Case 2, but addresses different amateur communities (cf. Figure 5.3). Domain experts are not well

Figure 5.4: Experts impart domain knowledge on Afghan cultural heritage (left); multimedia experts use 3D scanner to collect information (right)

involved in mobile multimedia management within the IKYDA project [GPS*10]. In cooperation with the Harokopio University in Athens and the Greek Navy, our non-linear storytelling platform *YouTell* has been applied at the former battleship “G. Averof” for the purpose of museum pedagogy [StKr08]. The battleship was transformed to a historical naval museum. Our team used a Riegl 3D laser terrestrial scanner to capture the 3D points of the battleship and created multimedia files (see Figure 5.4 right). Technology enhanced learning as well as cultural heritage management and museums take advantage of the adaptability of story templates. Many schools organize the students to visit and give history classes on board. The battleship “G. Averof” has played many important roles at different time periods for different purposes, which is learned by the students during their classes on board.

The main requirements in Case 3 include *interoperability* and *good push/pull mode*. High quality of multimedia stories are created for museum visitors and for school students to obtain related knowledge. The story content has to be adapted to different locations on the “G. Averof” battleship. The storytelling process considers the interoperability of platforms and delivery modes, because story listeners should be able to get story contents on different devices with or without their requests.

Case 4: Educational gaming. For gaming communities, different story templates can be used to create content for mobile gaming and to adapt location-based games such as mobile Scotland Yard [MBSC08] or Geocaching [GiGi10]. Mobile games can also be event-based, temporal information-based and community-based such as tracing the Olympic Games[3], learning platform design for serious games. For the domain experts, template-based storytelling is applied for game design to help cultural scientists get familiar with the on-site research environment [KCJa09].

[3]http://www.heise.de/newsticker/meldung/Vancouver-2010-Information-aus-allen-Kanaelen-927169.html

The main requirements in Case 4 focus on *high quality of stories*. Thus, story templates are applied to help storytellers create interesting and instructive stories of high quality.

Case 5: Movie story validation. Story templates facilitate movie fan communities to create good stories on their own interest. Moreover, story templates are used to check the feasibility of the storyline and the sequence of the story according to location and temporal context information. For example, whether it is possible to travel across Paris or Rome within 24 hours according to *The Da Vinci Code* or *Angels & Demons* could be an interesting and debating question for Dan Brown's fans? These fan communities can create and manage their own collection of photos and videos in oder to make a story with an adapted template.

Case 5 addresses the requirements of *reliability* on storytelling. The story plots and facts should be reliable so that story listeners can trust the storytellers.

In summary, various use scenarios lead to manifold requirements on storytelling. Ubiquity of multimedia is one of the main requirements among many others analyzed in [CHK*10]. As concluded in Table 5.2, four main elements can be used to guide the organization and browsing of multimedia for storytelling: community, context, multimedia semantics, and problems contributing to story sources. Smart mobile devices are not only used to access and distribute ubiquitous multimedia, but also are able to produce a great amount of multimedia files to enrich the multimedia repository. Mobile multimedia management is embedded in the cycle of multimedia story creation, access, and sharing on mobile devices and on the Web.

Cases	Community	Context	Semantics	Problems	Story sources
Case 1	multimedia amateur	location, time	rich metadata	domain knowledge imparting	event, learning
Case 2	multimedia amateur	location	tech. terminologies	technical knowledge	event, problem, navigation
Case 3	multimedia expert	location, time	rich metadata	serious gaming	learning, game
Case 4	amateur	location, (time)	domain specific	game design	game, navigation
Case 5	amateur: fan	location, time	domain specific	entertainment	game, navigation, event

Table 5.2: Case studies on multimedia storytelling

I employ i* [Yu97] for requirements modeling as depicted in Figure 5.5. The agents also include a set of story and user management services besides storytellers and story listeners. The both main agents *storytellers* and *story listeners* are dependent on user management, storytelling and story management services. Tasks consist of different operations on stories such as to get multimedia resources, to compose and view multimedia stories, to decompose multimedia in case of handling a large collection of multimedia artifacts, to share multimedia stories. The goal of achieving high quality multimedia stories can be adjusted by soft goals

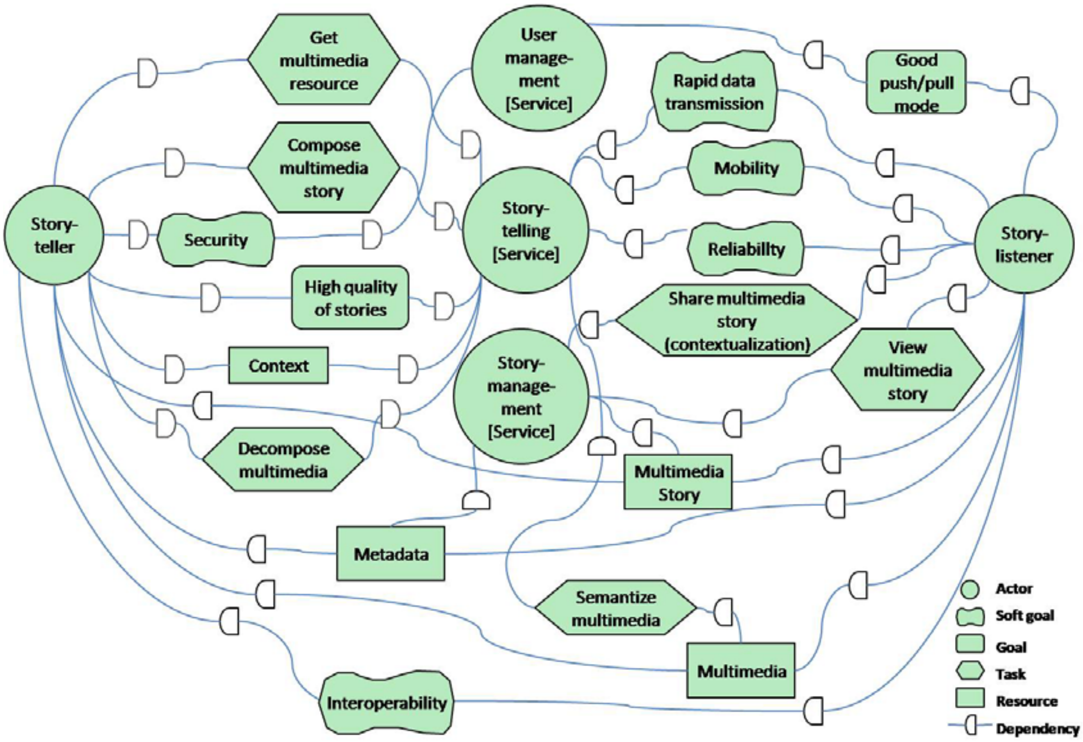

Figure 5.5: Requirements for multimedia storytelling

such as security, mobility, reliability, rapid data transmission, and interoperability. These soft goals are raised directly from the aforementioned case studies.

5.2 Template-based Storytelling

Based on the requirement analysis, storytelling process needs support of story templates first. Then the community aspects are considered as well. A well-constructed tree gives each thing a place [Wein07], while a well-organized storyline gives each piece of multimedia rich semantics. Modern information technologies provide various approaches to creating and sharing good digital stories [Mill04]. Some story templates which can be applied to help users tell good stories are introduced in this section. Template-based storytelling is the basic process for storytelling with regard to the community aspects, which is discussed later in Section 5.3.

5.2.1 The Data Model for Storytelling

A data model is proposed to serve as a guideline for storytelling service design. The entity relationship diagram for the template-based storytelling process depicted in Figure 5.6 has five key entities: *story project*, *story user*, *story*, *multimedia*, and *tag*. It is the underlying data model for the conceptual design of the storytelling prototypes *YouTell* and *YouTell TE*. More details are discussed in Chapter 6.

A *story project* is applied for knowledge of all entities involved in the storytelling processing. It takes a time period with start date and end date information. Within this time period, media creation and annotation, story template selection, story template adaptation, story creation, and annotation processes are carried out.

The *story user* represents a set of users with different roles within a story project. A story manager is in charge of story project management to coordinate all users especially storytellers and media producers.

Stories are created with various *multimedia* based on a certain story template. Multimedia is used to create a story with both semantic information and context information, which enables mobile production, access, and sharing of multimedia materials with time and location information. Tags are used as a label for metadata information to describe semantic information of multimedia, templates, as well as stories.

Tag is a central entity to unify the other entities. Tags are related to the community, semantics, and context aspects. Users tag multimedia, stories, as well as story projects. Tags can be assigned to each level of the multimedia collections.

Moreover, story templates facilitate multimedia amateur communities to create stories. Templates can be newly created, selected, adapted, or merged. The merge operations are similar to the graph operations introduced in Section 5.2.4. Since story template editors might have different versions of story templates, each of which need be managed. It is even possible for story template editors to work on the same template collaboratively.

In this data model context information, including networks, devices, time, location, and certain problems in the physical world, is the key for story creation, access, and sharing in a ubiquitous way to enhance multimedia ubiquity.

Above all, storytelling platforms are a kind of recommender systems to deliver proper multimedia content on a certain topic. Besides positive roles such as experts in storytelling systems, there might be some negative roles too, e.g. spammers or trolls in communities.

5.2.2 The Template-based Storytelling Process

Good stories or classic films can be told or watched again and again, because good stories bring fun, passion, lessons learned, and other added values to the audience. In the film and TV industry or other rich entertainment media production branches directors, playwrights, camera men, special effect personals work together to create stories in a professional way. There is sufficient technological support for professionals to create stories.

The success of professional communities has been proven by many films. But fan communities as well as so-called amateurs do not have appropriate and adequate support to operate

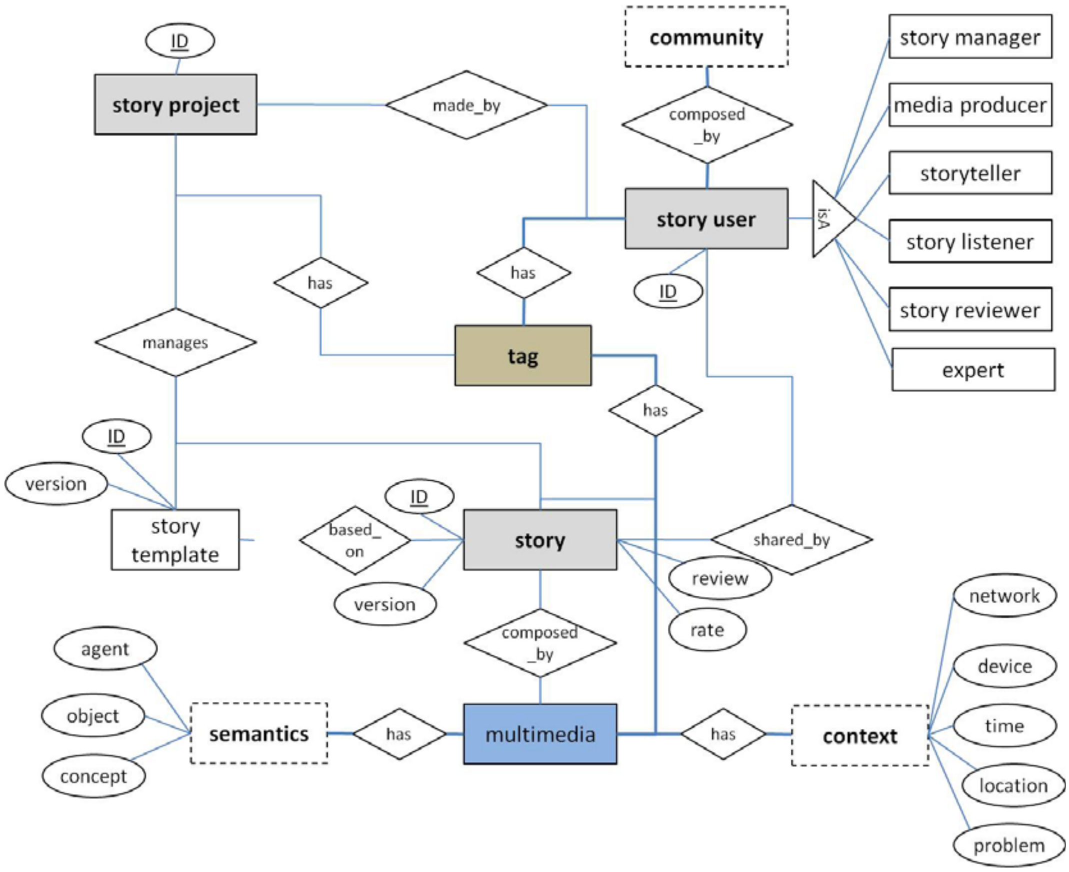

Figure 5.6: The data model in ERD

on various multimedia materials. Although user communities have mastered approaches to contributing to a large amount of knowledge repository on the Internet with mobile devices and Web 2.0, multimedia is often shared in a monotonous way. Users can share pictures at Flickr or Picasa, while sharing videos at YouTube or Vimeo. It is not supported well to integrate and share different media types. Social aggregation has been applied to collect users' RSS feeds across platforms (cf. Figure 3.7). However, users still lack a simple method to aggregate multimedia content. Hence, I explore substantial multimedia aggregation via digital multimedia storytelling approach for common user communities.

To facilitate "amateur" user communities with multimedia storytelling, the concept and the approach of story templates are applied to enhance the interoperability and adaptation.

The storytelling process can be modeled as depicted in Figure 5.7 with three main element groups: *story project* to manage all entities involved in the storytelling process, *story users* who create and consume stories, and *story sources* from which a story is built.

The stories consisting of a sequence of multimedia files are created, told, and shared within the respective communities. Each story is created or contributed by some story sources. A story source can be a certain problem, an event, for the purpose of a game setting, or for a trip plan or report with navigation across locations. An appropriate story template is able to help storytellers create or tell a good story based on a certain story source. Two story templates are suggested: the movement oriented design pattern (with or without the problem-solution tree) and the hero's pattern. The template management is extensible and more templates available can be easily integrated. Both stories and story templates are managed in a story project, so that the connections between them can be consolidated and a version control can be well applied at the same time.

A story is the right appropriate digital form to embody or to connect with the story sources in the physical world. Story sources have various context information including spatial and temporal context. Multimedia composing stories has semantics which can be represented by tags. The association between semantics and context information is realized via information flow between a story itself and the story source. A mapping can be established between semantics and context information.

As mentioned before, the storytelling process is a contextualization process. Contextualization includes targeting different users and communities on the one hand. On the other hand, stories are connected to certain sources and aim to solve some problems. However, the semantization process is not excluded. Storytelling enhances multimedia semantics as well. Mobile multimedia management is tightly associated with story sources which have rich context information. Story users are enabled to access, organize, and share multimedia via storytelling. They can also be grouped into certain communities if necessary.

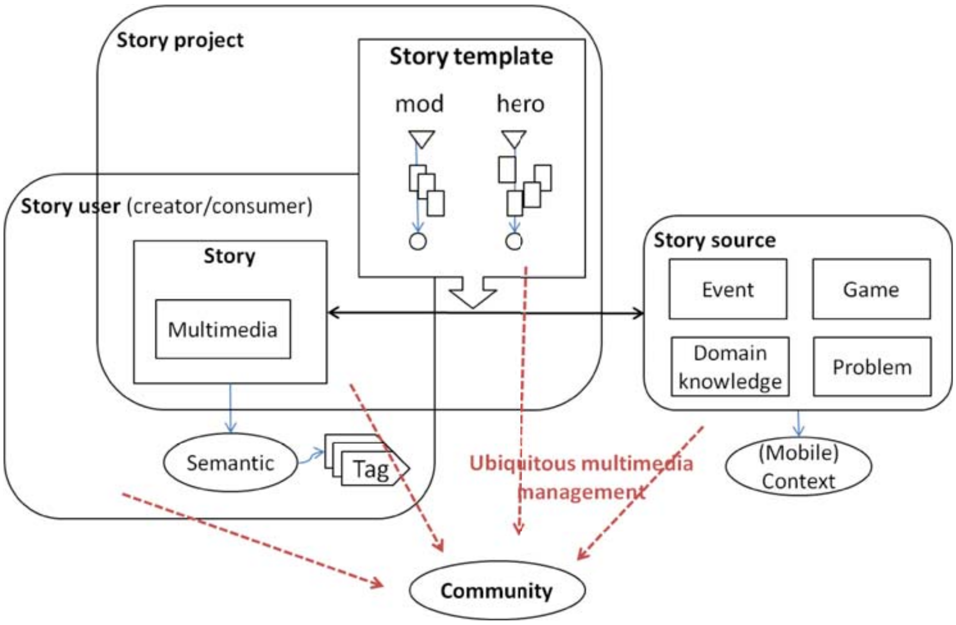

Figure 5.7: The template-based storytelling model

5.2.3 The Story Templates

Two different kinds of story templates are considered and analyzed. We formalize them and discuss the potential usage for the aforementioned storytelling scenarios for communities of practices [CKJa11].

The *Movement Oriented Design (MOD)* paradigm [Shar05, SKSJ06] is a methodology for creation of linear and non-linear multimedia stories. The main idea is to bring together different theories, models, and tools. The MOD paradigm formalizes the ways to create multimedia stories by combining three vital facets of stories: motivation, exigency, and structure. Thus, the MOD methodology is a comprehensive framework for the creation of non-linear digital stories. We realize the MOD paradigm with the following formalization.

Two structures are defined: non-linear multimedia stories S and their problem hierarchies P_S. The universes of both structures are based on a common set of identifiers defined as follows:

$I \subseteq N$ with: $I = I_{CSU} \cup I_P \cup I_M$

where I_{CSU}, I_P and I_M are identifiers for composed story units (CSU), problems addressed (P) and the media (M) contained in a story.

Given the signature

$\sigma = CSU, M, Rel_{SUCC}, Rel_B, Rel_M, Rel_E, root$

with: $CSU, M \in R^1(\sigma)$
$Rel_{SUCC}, Rel_B, Rel_M, Rel_E \in R^2(\sigma)$ and $root \in F^0(\sigma)$

Then, a σ-structure

$$S = (SU, CSU^S, M^S, Rel^S_{SUCC}, Rel^S_B, Rel^S_M, Rel^S_E, root_S)$$

represents a MOD story.

The presentation of the problem as a starting point and several potential solutions can be connected to MOD as an option. Storytellers can decide whether they want to specify problems and solutions for a digital story. Given the signature $\sigma = P, M, L, root, super$ with:

$P, M, L \in R^1(\pi)$ and $RelPM \in R^2(\pi)$

$root \in F^0(\pi)$ and $super \in F^1(\pi)$

Problems addressed by a story S are defined given the following structure P_S:

$P_S = (P_S, P^{Ps}, M^{Ps}, L^{Ps}, root^{Ps}, super^{Ps})$

defines a valid story plot of problems if the following conditions are fulfilled. The signature σ and a problem structure P_S have the following meaning given the previous conditions: The universe PS of P_S is the union of problems P covered by a story together with the media M. More details can be found in [SKSJ06].

Related to the aforementioned use cases, MOD can be well applied for Case 2. The problems are usually addressed as how to use and operate a technical device correctly. The solutions are the usage manuals for different sub tasks to operate the devices. Multimedia is well employed to illustrate the solutions as an intuitive means. Case 3 can apply this template as well, in order to present the track of a cultural object in different time periods and at different locations. MOD specifies the story structure with problems and solutions. However, the recursive divisions into composed story units do not give an explicit support for better storytelling. A universal story template needs to be surveyed and employed, e.g. Campbell's monomyth.

In addition, the *Hero's Journey template* depicted in Figure 5.8 has been the source of a vast majority of successful stories and movies. A very few stories contain all of these stages - some stories contain some of the stages, while others contain only part of them. Some

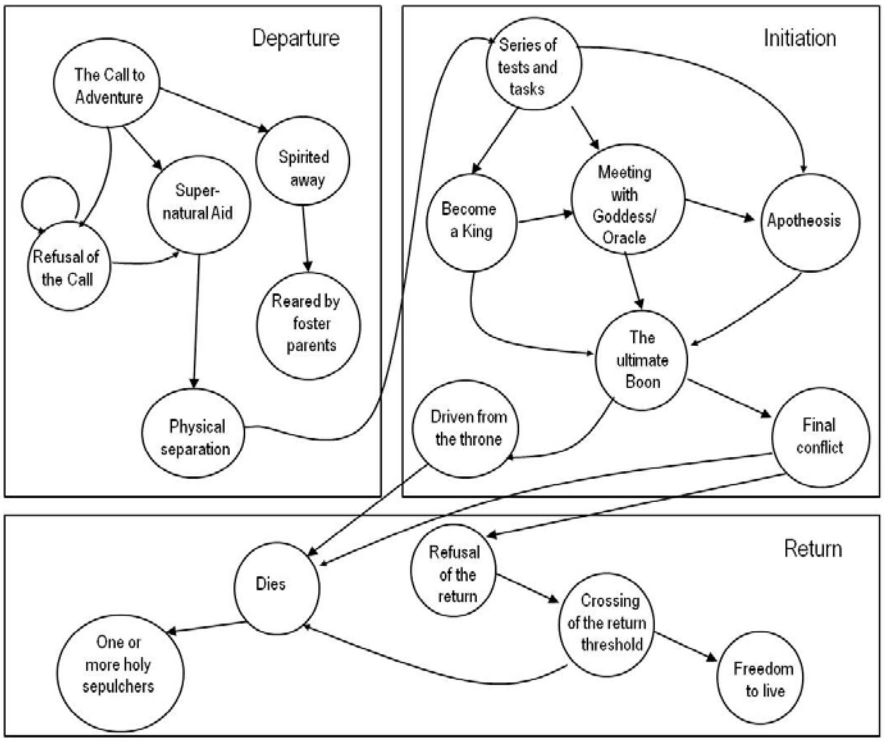

Figure 5.8: Joseph Campbell's The Hero's Journey template

may only focus on one of the stages, while others may deal with the stages in a different sequence. These stages may be organized in a number of different ways. One typical stage model is a division of three sections: departure, initiation, and return. Users have to decide which stages they want to include in their own story, which can be dealt with as a story template. After that users are able to add multimedia to the nodes at different stages from the adapted template.

Related to the previously introduced scenarios, Case 1 and Case 4 can apply this story template to create stories to cover the generational knowledge gap, and to create some computer game setting for vocational training purpose. The complexity and variety of this template can represent the complicated knowledge transfer process in a suitable way. The storylines of many films originate from this template. Thus, this template can be applied with underlying context information of storytellers for Case 5.

Since a large number of good stories are based on the *Hero's Journey template*, the great variety also shows the high complexity of applying this template. Additional tools are required to help storytellers deal with this template.

In summary, both of the story templates can be applied for different use cases in CoP to enhance mobile multimedia management. Due to the complexity of the story templates, a template engine is required to adapt and merge different templates. Since the template engine is open and extensible, it is possible to input and manage more story templates for

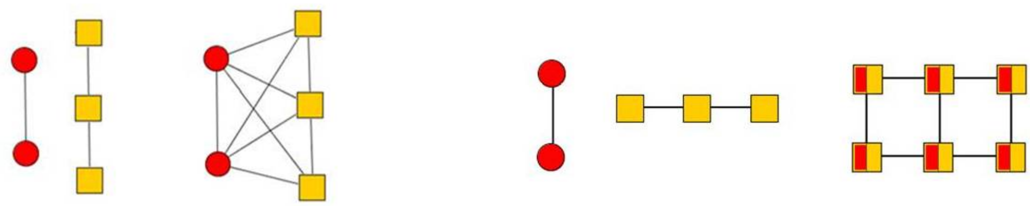

Figure 5.9: Graph join operation (left) and Cartesian product operation (right)

users' storytelling process. And the realization of template-based storytelling platforms is discussed in Chapter 6.

5.2.4 Graph Operations for Story Templates

Since storytellers are offered with the story templates, they also need tools to adapt the templates or combine more than one templates. The complexity of story components based on story templates can be described using the graph operations specified in graph theory. For this reason the binary operations are surveyed how to create a new graph from two initial graphs $G_1 = (V_1, E_1)$ and $G_2 = (V_2, E_2)$. The main graph operations and their advantages and disadvantages are discussed respectively. Especially, the use of these operations in story template adaptation and mashup is introduced.

Graph join: Figure 5.9 left

The join $G = G_1 + G_2$ of graphs G_1 and G_2 with the disjoint vertex sets V_1 and V_2 and the edge sets X_1 and X_2 is a graph union $G_1 \cup G_2$ which includes all vertex from V_1 and V_2 together with all the joining edges. This graph operation shows all possible paths of CSU concerning the problem-solutions in the MOD template.

Let $G_1 = CSU$, $G_2 = P_S$, a complete story based on MOD is $CSU \cup P_S$.

The result of this operation is a new graph with a more complicated story structure. It could be unclear for the users to follow all the story paths after the join operation. But storytellers can select the path and create a MOD-based story on demand.

Graph Cartesian product: Figure 5.9 right

The Cartesian graph product $G = G_1 \times G_2$ of graphs G_1 and G_2 with the disjoint vertex sets V_1 and V_2 and the edge sets X_1 and X_2 is the graph with the vertex set $V_1 \times V_2$ and $u = (u_1, u_2)$ adjacent with $v = (v_1, v_2)$ whenever $[u_1 = v_1$ and $u_2 adj v_2]$ or $[u_2 = v_2$ and $u_1 adj v_1]$. This operation is also applicable to the MOD template with $CSU \times P_S$. For more complicated stories it is possible to raise story proofs. For this reason some proper restrictions or rules should be specified.

Rooted product of graphs: Figure 5.10

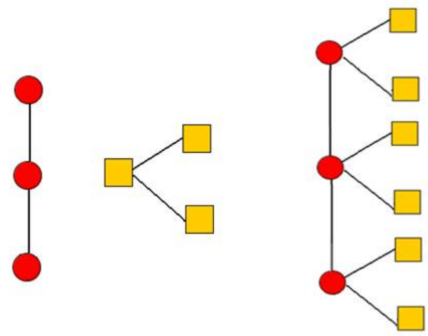

Figure 5.10: Graph rooted production operation

In mathematical graph theory, the rooted product of a graph G and a rooted graph H is defined as follows: take $|V(G)|$ copies of H, and for every vertex v_i of G, identify v_i with the root node of the $i-th$ copy of H.

Formally, assuming that $V(G) = g_1, ..., g_n$ and $V(H) = h_1, ..., h_m$, the root node of H is h_1, define $G \circ H := (V, E)$ where $V = (g_i, h_j) : 1 \leq i \leq n, 1 \leq j \leq m$ and

$$E = (g_i, h_1, (g_k, h_1)) : (g_i, g_k) \in E(g)$$

$$\cup \bigcup_{i=1}^{n} ((g_i, h_j), (g_i, h_k)) : (h_j, h_k) E(H)$$

If G is also rooted at g_1, one can view the product itself as rooted, at (g_1, h_1). The rooted product is a subgraph of the Cartesian product of the same two graphs. This operation is an extension of the operation Graph Cartesian product.

Graph intersection

Let S be a set and $F = S_1, ..., S_p$ a non-empty family of distinct non-empty subsets of S whose union is $\bigcup_{i=1}^{p} S_i = S$. The intersection graph of F is denoted as $\omega(F)$ and defined by $V(\omega(F))$, with S_i and S_j adjacent whenever $i \neq j$ and $S_i \cap S_j \neq \emptyset$. Then a graph G is an intersection graph on S if there exists a family F of subsets for which G and $\omega(F)$ are isomorphic graphs. This operation simplifies the graphs. This condition of isomorphic is often hard to be fulfilled in story components.

Series and parallel composition of graphs

A two-terminal labeled graph (G, s, t) consists of a graph G with a marked source s and a sink t. A two-terminal series-parallel graph is a graph that may be constructed by a sequence of series and parallel compositions starting from a set of copies of a single-edge graph K_2 with assigned terminals. In other words a graph is a series-parallel graph, if it may be turned into K_2 by a sequence of the following operations:

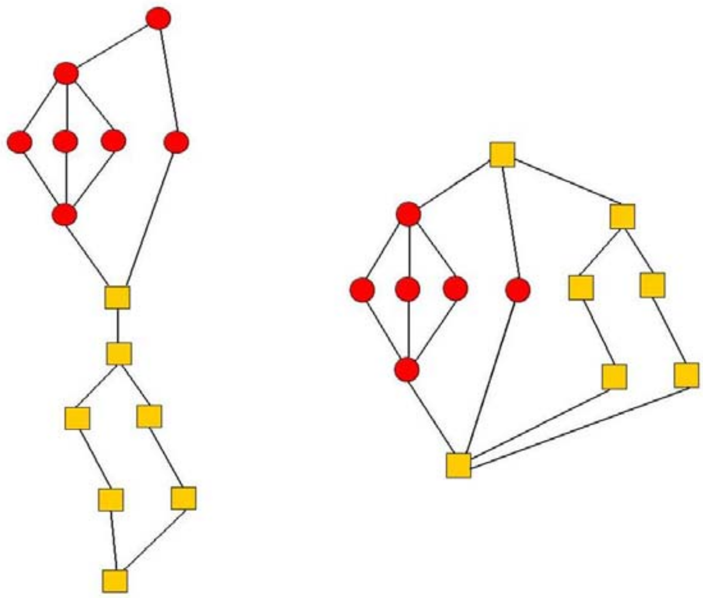

Figure 5.11: The series (left) and parallel (right) composition operation

- Replacement of a pair of parallel edges with a single edge that connects their common endpoints;
- Replacement of a pair of edges incident to a vertex of degree 2 other than s or t with a single edge.

The series composition depicted in Figure 5.11 (left) $Sc = Sc(X, Y)$ of two-terminal graphs (TTGs) X and Y is a TTG created from the disjoint union of graphs X and Y by merging the sink of X with the source of Y. The source of X becomes the source of Sc and the sink of Y becomes the sink of Sc.

This series composition operation can be applied to compose a long story based on several short stories. The end of the previous story need be related to the start of the next story.

The parallel composition depicted in Figure 5.11 (right) $Pc = Pc(X, Y)$ of two TTGs X and Y is a TTG created from the disjoint union of graphs X and Y by merging the sources of X and Y to create the source of Pc and merging the sinks of X and Y to create the sink of Pc.

The parallel composition operation can be applied to enhance story non-linearity. One branch more is added when one parallel composition is carried out.

Both composition operations are appropriate to merge the variants of *the Hero's Journey template*. Generally, those simple graph operations are required by the MOD template, while those complicated ones are more suitable for the hero's template.

5.3 Community-based Storytelling on Web 2.0

The concept of *communities of practice* is discussed to help storytelling communities find and have their own roles. Community-based multimedia storytelling approach can reorganize multimedia content with multimedia semantics, context information, and different communities. Users are encouraged to give more feedback to stories, which can reduce false multimedia semantic information by reuse of multimedia data.

5.3.1 The Role Model for Community-based Storytelling

Good stories embed much information and knowledge. The requirements to share interpretation can be met in community of practice. Users can be assigned with various roles to collaborate on multimedia stories by storytelling. A new user gets necessary rights to execute basic features like tagging, viewing, rating, clustering, and searching for a story. User communities are grouped into different clusters according to their own interests or preferences.

Story users build up a community or several communities. A comprehensive role model is needed to identify and manage story users, which also helps story users interact among themselves during the storytelling process. Story users can act as different roles as depicted in Figure 5.12. A user *John Doe* gets necessary rights to execute basic features like tagging, viewing, rating, and searching for a story.

Experts are users who have the knowledge to help the others. There exist three different sub roles. A *technician* can aid users with administrative questions. A *storyteller* knows how to tell a thrilling story. And finally a *maven* is characterized as possessing good expertise. A user has to give a minimum number of good advices to the communities in order to be upgraded to an expert.

Administrators have extended rights which are necessary for maintenance issues. The *system admin* is allowed to change system and configuration properties. *Story sheriffs* can delete stories and media. Additionally, *user admin* manages users and is allowed to block or delete them.

A *producer* creates, edits, and manages stories. The producer role is divided into the *production manager* who is responsible for the story project, the *author* who is responsible for the story content, the *media producer* who is responsible for media in use, the *director* who is responsible for the story, and finally the *helper* who is an assistant for the story project.

The role called *bandit* refers to users who want to damage the system. According to their different behavior, they can be a *troll*, a *smurf*, a *hustler* or a *munchkin*.

In contrast to *bandit* there exist two prestige roles: the *connector* and the *domain lord*. Whereas the *connector* knows many people and has a big contact network, the *domain lord* has both a great expertise and, at the same time, is an excellent storyteller.

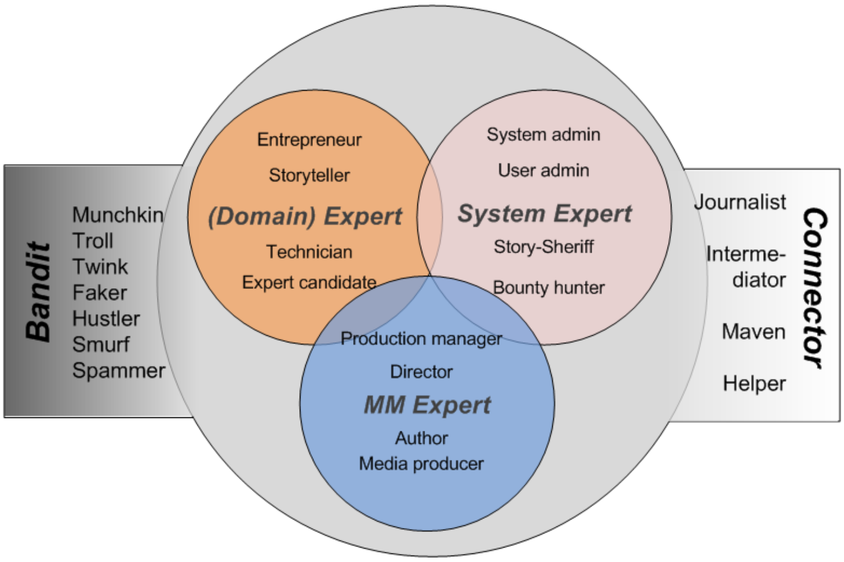

Figure 5.12: The role model for community-based storytelling

Users of these different roles play different parts in the storytelling process. It is instructive to observe how the major role has been exchanged from experts to amateurs or wide crowds. Here, experts refer to those who use traditional media such as films and TV, while amateurs and wide crowds are emergent super stars or invisible heroes or heroins on the Web 2.0. In this sense, the differentiation between experts and amateurs are independent to domain knowledge.

Experts are a growing group out of amateurs. The reasons are that experts have personal reputation in online communities, which is considered as an important motivational factor to participate in topic-centered communication spaces, and topic-centered materials are key content in recommender systems [RVWu07].

5.3.2 Profile-based Story Searching

Users of different roles also influence the story search process. Especially, experts or domain lords are assumed to possess better stories. Figure 5.13 depicts how the profile-based story search algorithm works.

The set of all stories which haven't been seen or created by the user are described through $S = \{S_1, ..., S_n\}$. The function $\mu : S \longmapsto WL$ assigns a set of tags to a story, R is the set of all ratings, R_{S_i} is the set of ratings of story S_i, $S_i \in S$.

Input of the algorithm is a user made tag list $W = \{sw_1, ...sw_k\}$. Additionally further information is necessary: the maximal result length n and the set of story ratings B of user with a similar profile. For computation of these users the Pearson r algorithm is taken (cf. [ShMa95]).

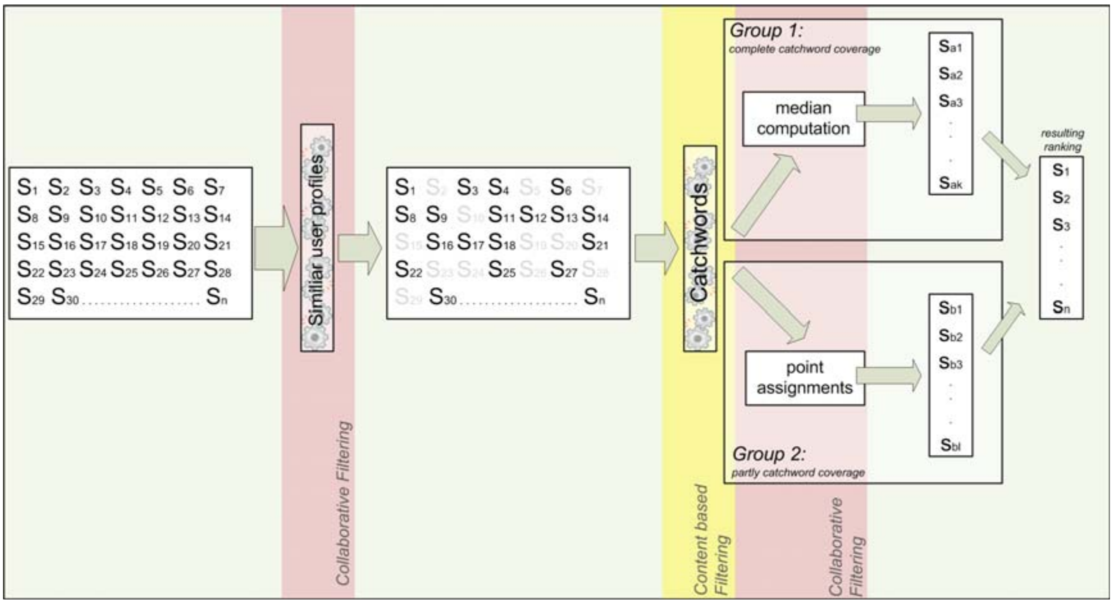

Figure 5.13: Profile-based story search algorithm

Those users with similar or opposite ratings are taken into consideration. If the ratings are similar the Pearson value is near to 1, if they are opposite the value is near to -1. In the first case stories with similar ratings, in the second case stories with opposite ratings are recommended. The value has to be in a threshold L to be suitable. The Pearson value is computed with the following formula:

$$w_{a,b} = \frac{\sum_{i=1}^{m}(r_{a,i} - \overline{r_a}) \cdot (r_{b,i} - \overline{r_b})}{\sqrt{\sum_{i=1}^{m}(r_{a,i} - \overline{r_a})^2 \sum_{i=1}^{m}(r_{b,i} - \overline{r_b})^2}}$$

The Pearson value between user profile a and compared profile b is represented through $w_{a,b}$. The variable m corresponds to the story count, i is a particular story and r is its rating. The average ratings of profile a is displayed through $\overline{r_a}$.

It holds $B = \{B_{S_1}, \cdots, B_{S_k}\}$ with $S_i \in S, 1 \leq i \leq k$. Furthermore, B_{S_i} corresponds to the set of story ratings of user with a similar profile for story S_i and finally it holds $\lambda(R_{S_i}) = B_{S_i}$ where λ defines the method to compute similar rating results from all story ratings. This computation procedure is as follows:

1. step:

Group the stories: The first group G_1 corresponds to the story set $S_1, \cdots, S_m$, $S_i \in S$ with $W \subseteq \mu(S_i)$ and $\lambda(R_{S_i}) \in B$. The second group G_2 contains the stories $S_1, \cdots, S_l$, $S_j \in S$ with $\mu(S_j) \cap W \neq \emptyset, W \nsubseteq \mu(S_j)$ and $\lambda(R_{S_i}) \in B$.

2. step:

(a) Take group $G_1 = \{S_1, \cdots, S_m\}$.

   (i) Compute the story ratings media B_{S_i} for every story S_i.

   (ii) Build a ranking corresponding to the media

(b) If $|G_1| < n$, take group $G_2 = \{S_1, \cdots, S_l\}$.

   (i) Is $P : S \longmapsto \mathbb{R}$ a function, which assigns a number of points to every story.

   (ii) For every $j, 1 \leq j \leq l$ it holds $P(S_j) = 0$

   (iii) For every tag sw_i

   For every storyS_j

   If $sw_i \in \mu(S_j)$:

   Compute the media m_j of ratings B_{S_j}

   Map the result to the range [1,5]: $m'_j = m_j + 3$

   $P(S_j) + = m'_j$

   (iv) Sort the stories by their scores.

(c) Build an overall ranking with the rankings from group 1 and group 2. This ranking is the output of the algorithm.

5.3.3 Expert Finding Algorithm

Web 2.0 operations like tagging and especially feedback influence on expert-finding. Users can give feedback to stories and for expert advices. Feedback is very important for storytelling, because it delivers fundamental knowledge for executing the profile-based search and for defining the user's expert status. Furthermore, the visualization of feedback results (i.e. average ratings, tag clouds) help users get an impression of the experts/story's quality.

Explicit and implicit feedback techniques are used as well. After visiting a story respectively getting an expert advice the user has the possibility to fill out a questionnaire. This explicit form of giving feedback is fundamental for storytelling. But not every user likes filling out questionnaires. Therefore, implicit feedback is also employed. Although this is not as accurate as explicit feedback, it can be an effective substitute. It is also assumed that the more often a user visits the story, the more interesting it is. The more frequently a story is visited by all users, the more popular it is.

Users who have questions can contact an expert. A special algorithm and useful user data are necessary to determine the users' knowledge, in order for the users to find the best fitting expert.For every user there exists a user profile which contains the following information:

- *Story data* is generated when a user visits or edits a story.
- *Expert data* is created with given/received expert advices.
- *Personal data* represents the user knowledge the user has acquired in the real world. This data is typed in by the user itself.

With this information three tag vectors are created. They are weighted, summed up, and normalized. Such a vector has the following form:

$$\begin{bmatrix} tag_a & value_a \\ tag_b & value_b \\ tag_c & value_c \\ \cdots & \cdots \end{bmatrix}$$

The final value of each tag represents the users' knowledge assigned to the related tag. A value near to zero implies that the user only knows few, where as a value near 1 implies expertise at this topic.

Next, the data vector is composed as follows. First the story data vector is created. For every story a user has visited and for every story for which the user is one of the producers, the corresponding story/media tags are stored in a vector. The respective value is computed with the formula $value = AV \cdot DF \cdot BF$ and:

- $AV \hat{=}$ count of appearances of a tag
- $DF \hat{=}$ date factor: The older a date, the more knowledge is lost. The value lies between 0 and 1. 1 stands for an actual date, and 0 for a very old one. It is assumed that the week number should not be greater than 80. Four weeks correspond to a knowledge deficit of 5 percent. It holds: $DF = 1 - (\lfloor \frac{\#weeks}{4} \rfloor \cdot 0.05)$.
- $BF \hat{=}$ rating factor: This value is computed by the explicit and implicit feedback which has been given.

Then the story data vector d is computed:

$$d = \text{Story visit vector} \cdot 0.35 + \text{Story edit vector} \cdot 0.65.$$

After that a normalization to the range $[0, 1]$ is computed: Let $S = \{s_1, ..., s_n\}$ be the set of all tags, which occur within the set of data vectors and let $v(s)$ be the corresponding value.

$$\forall s \in S v(s)_{\text{norm}} = \frac{v(s) - v_{min}}{v_{max} - v_{min}}$$

$$\text{and } v_{min} = \min\{v(s_1), ..., v(s_n)\}, v_{max} = \max\{v(s_1), ..., v(s_n)\}.$$

In a second step the expert data vector is computed. For every expert advice a user has given/ obtained the corresponding tags are stored in a vector. The respective value is calculated analogously to the above computation and it holds:

$$\text{expert data vector} = advice_{\text{given}} \cdot 0.8 + advice_{\text{obtained}} \cdot 0.2.$$

Third, the personal data vector is computed. With the information the system gets from the user tags and its corresponding values obtained, this information is taken for this vector.

In a last step the final vector is computed:

$$\text{data vector} = 0.4 \cdot \text{expert data vector} + 0.4 \cdot \text{story data vector}$$

$$+0.2 \cdot \text{personal data vector}.$$

To find an expert first a vector $v = \{s_1, w_1, ..., s_m, w_m\}$ is created with the tags the user has specified. Then this vector is compared with all existing data vectors $w_1, \cdots, w_n$. The user with the best fitting vector is the recommended expert.

The vectors have the following form:

$z = (s_1, w_1, s_2, w_2, \cdots, s_m, w_m)$, whereas s_i is the i-th tag and w_i is the corresponding value.

(a) Repeat for every vector $w_j, 1 \leq j \leq n$

(b) $\quad$ $\text{diff}_j = 0$

(c) $\quad$ Repeat for every tag $s_i, 1 \leq i \leq m$ of vector v

(d) $\qquad$ If $s_i = s_{j_k}, s_{j_k} \in w_j$: $\text{diff}_j = \text{diff}_j + (w_i - w_{j_k})$

(e) $\qquad$ else $\text{diff}_j = \text{diff}_j + 1$

Output of this algorithm is the user for which data vector u holds:

$u = w_j$ with $\text{diff}_j = \min\{\text{diff}_1, \cdots, \text{diff}_n\}$.

5.4 Related Work on Storytelling Platforms

The advances of this community-based storytelling approach with story templates are obvious after I have made a survey of the existing storytelling platforms. And a comparison is made based on various aspects of storytelling methods.

Web 2.0 allows more and more knowledge to be created, managed, and shared by communities themselves. Because Web 2.0 technologies were not intended specifically for digital storytelling, many challenges are raised by the readiness of communities to accept these technologies. However, already on the "classical" Web the power of storytelling was well recognized. There exist a lot of virtual communities like Fray.com[4] whose content is solely built of personal stories shared by the community members. Software like MemoryMiner[5] is capable of facilitating the authoring of digital stories even for non-experienced computer users. In oral history research web archives like the Shoah archive[6] or the Densho project[7] are created to preserve generational knowledge. In the context of corporate learning storytelling is also known and used [NoTa95, DaPr98, BrDu00]. A very comprehensive collection of resources is available on the Internet[8].

Figure 5.14 gives an example of how online newspapers use multimedia to tell stories in a linear pre-order. Many storytelling applications and platforms have been developed. Some multimedia sharing social network sites like Flickr and YouTube are popular for sharing stories. Users can specify tags and give feedback to the multimedia content. Even more metadata is extracted automatically from images than from videos. The popularity of multimedia can be measured by the viewing frequencies which are recorded by the system. With the wide spreading of those stories, a lot of civil journalists [Rhei03] and Web idols especially in the adolescence communities are emerging. In the Web 2.0 world, users are enabled to integrate as well as combine several multimedia content according to their preferences by means of creating playlists or collections. Unfortunately, more interaction is not supported.

Usually there are no story templates to assist storytellers to tell interesting and well-structured stories. Table 5.3 lists the comparison results of these related storytelling platforms.

Alice developed at Carnegie Mellon University is a programming learning environment through storytelling with 3D characters. Storytelling is used to create computer-animated videos to motivate school students to learn computer programming. A large collection of 3D characters stimulate the plots of stories [KePa07].

Art-scene (Analyzing Requirements Trade-offs: Scenario Evaluations) developed by City University of London [ZaMa04] is an interactive tool for discovering, acquiring, and describing requirements for new systems using scenarios.

BBC Telling Lives[9] of your digital stories launched by British television channel BBC provides opportunity for British residents to make their own stories. Digital stories created

[4] fray.com/is/
[5] www.memoryminer.com
[6] www.shoahproject.org
[7] www.densho.org
[8] tech-head.com/dstory.htm
[9] http://www.bbc.co.uk/tellinglives/

Figure 5.14: An example of multimedia storytelling in online newspapers

are short films made by people using computers and personal photo collections. The application is limited to certain regions.

ComicLife[10] is an iPhone application supporting storytelling with streamlined image selection, cropping and placement, authentic speech bulbs captions and special effects text (see Figure 5.15 right). It targets at creation of comics, photo albums, and explanation of how-tos. It offers templates for photo layouts. The created stories can be shared online or via email.

Dramatica [PhHu01] is a comprehensive framework suitable to create multimedia stories with semantic knowledge. However, it does not allow any kind of non-linearity.

Einestages[11] (*English:* Once upon a time) is a history-based storytelling Web site hosted at German online newspaper Spiegel Online. It collects text and multimedia files including images, videos, and audios from user communities to build up a collective memory for the history. In the German language, *story* and *history* shares the same word. The editors select a topic everyday, invite readers who witness the history, and collect story materials from readers.

iPhoto[12] running on Mac OS can link a series of photos and music and make up a linear story in video format. It is deployed for users to organize their personal photo galleries, to

[10]http://plasq.com/
[11]http://einestages.spiegel.de
[12]http://www.apple.com/ilife/iphoto/

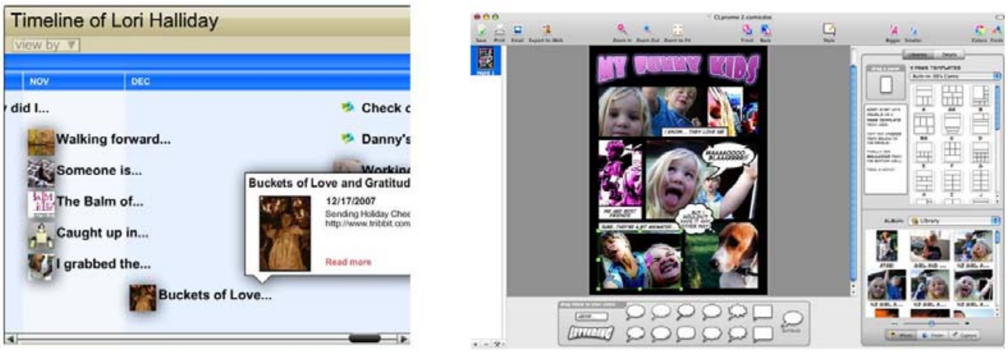

Figure 5.15: Screenshots of OurStory (left) and ComicLife (right)

input photos from iPhone or digital cameras easily, to create a slide show with a desired sequence, and to publish in Internet as well as to send to printing services. A loop of multimedia management makes multimedia creation and sharing across various devices and browsers seamless.

Inscape supports the authors along the whole story creation process. Various multimedia forms are supported such as theater, movies, cartoons, puppet shows, video games, interactive manuals, training simulators, etc. Thus, even users with average computer skills are able to complete interactive stories and create simulations [GBFe05].

OurStory[13] allows saving stories, videos, and photos on a collaborative timeline (see Figure 5.15 left). OurStory is a social networking web-site that helps users capture, share, and preserve stories, photos, and videos. These are organized into a visual timeline. The story environment is a linear one. The pages are chronologically displayed and contain text (the actual story) mixed with photos or videos. The application can mostly be used as an online journal, online diary or as a blog. Users can choose how and with whom to share their live stories through email and/or on their personal timeline.

QWiki[14] aims to enhance user experiences about information based on Wikis. Users get to learn knowledge about people, objects, and places via organized multimedia files. Figure 5.16 shows two main screenshots of QWiki. On the left side, multimedia files including images, videos, audio files, and text documents are integrated and displayed as a mosaic. The tab on the right screenshot shows the organization of the related multimedia files. The stories are told by a group of experts in a linear sequence.

Scratch[15] enables users to create and share their own interactive stories, games, music, and art. Scratch aims to help school kids develop new learning skills with media. When school kids create and share Scratch projects, they learn important mathematical and computational ideas, while also learning to think creatively, reason systematically, and work collaboratively.

[13] http://www.ourstory.com//
[14] http://www.qwiki.com
[15] http://scratch.mit.edu/

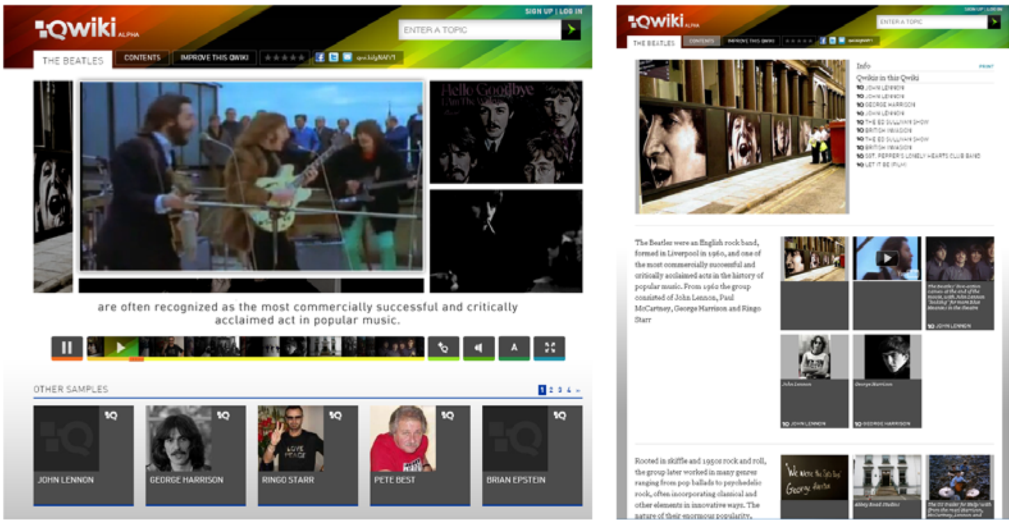

Figure 5.16: Screenshots of QWiki

The Scratch Online Community is designed along these lines to be a source of inspirational ideas, to provide an audience for children's creations and to foster collaboration among its members.

StoryBird[16] is a service of collaborative storytelling. One (or more) people create a Storybird in a round robin fashion by writing their own text and inserting pictures. Then they have the option of sharing their Storybird privately or publicly on the network. The final product can be printed, watched on screen, played with like a toy, or shared through a worldwide library.

Our research prototype *YouTell* [CKMa08, SKSJ06] embeds digital non-linear storytelling in a collaborative Web 2.0 environment with expert knowledge and recommendation. It is a part of the Virtual Campfire scenario. The Web 2.0 features such as tagging and ranking stories are also employed. Story search algorithms are developed including a profile-based algorithm. In addition, experts with certain knowledge can be identified in communities of practice. The storytelling process is intertwined with a set of Web 2.0 approaches and expert finding.

The Virtual Campfire YouTell storytelling platform fulfills the requirements better especially in the aspects of collaborative storytelling, multimedia support, cross-platform with mobile interfaces, support of non-linearity, and adaptive storytelling based on story templates.

[16] http://storybird.com/

Systems	Web 2.0	Collabo-rative	Multimedia support	Cross-platform (mobile)	Non-linearity	Story template (adaptive)	Interactive
Alice	very poor	good	good	poor	good	good	good
Art-scene	very good	good	good	good	good	very poor	very poor
BBC Telling Lives	poor	poor	good	good	good	very poor	very poor
Comic Life	very good	poor	good	good	poor	poor	poor
Dramatica	poor	poor	very good	good	poor	very poor	poor
Einestages	good	poor	good	good	poor	very poor	poor
Inscape	poor	poor	very good	good	poor	very poor	very poor
iPhoto	very good	good	very good	poor	poor	good	good
OurStory	very good	good	very good	good	poor	poor	good
QWiki	very good	good	very good	good	poor	good	good
Scratch	poor	good	good	good	poor	good	poor
StoryBird	very good	very good	poor	good	very poor	poor	poor
VC:YouTell	good	very good	very good	very good	very good	very good	good

Table 5.3: A comparison of the existing storytelling systems

Über die allmähliche Verfertigung
der Gedanken beim Reden

An essay by Heinrich von Kleist
(1777 - 1811)

Chapter 6

Validation in Mobile Community Information System Applications

Several mobile community information systems have been developed and applied the conceptual research on various tagging approaches and multimedia storytelling approaches to uncertainty handling. The semantization and contextualization processes are focused via multimedia semantics and context management. This chapter gives technical details on realization of these systems called CAAS, ACIS, SeViAnno, CCPLE, and YouTell within Virtual Campfire. The mobile issues of these community information systems are discussed subsequent to each system, if any mobility measures have been carried out. The uncertainty 2.0 handling model is validated through realization and evaluation of these mobile community information systems.

6.1 The Virtual Campfire Scenario

The scenario of *Virtual Campfire* developed within the German Excellence Research Cluster UMIC serves as a super scenario for a number of sub scenarios in different user communities. The name has come up, because people like to gather together around a campfire to tell anecdotes and stories. Virtual Campfire aims to provide a virtual storytelling place for multimedia sharing with enhanced multimedia semantics and context.

Within the UMIC project, the prototypes have been demonstrated for many times and have received feedback. To stress the requirements from the communities, mobile communities within Virtual Campfire are analyzed. Then the general architecture of Virtual Campfire is discussed. The prototypes have been realized based on this architecture and validated the proposed approaches in Chapter 4 and Chapter 5.

Virtual Campfire deals with complex tasks on mobile multimedia management. First of all, multimedia is a complex of different media types including images, videos and 3D models.

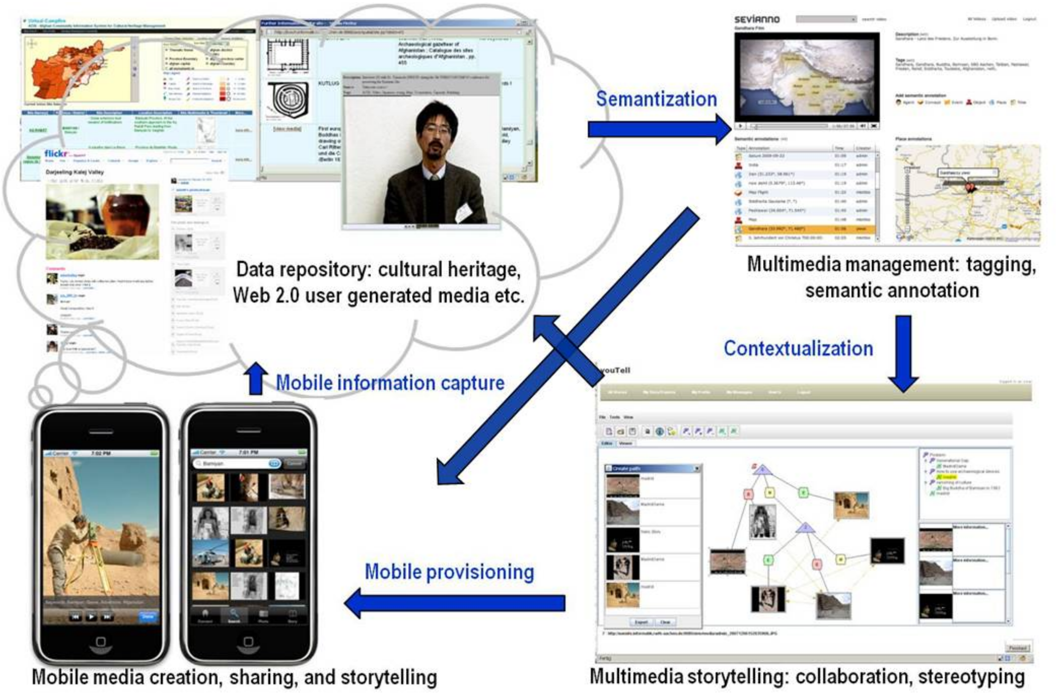

Figure 6.1: A mobile multimedia management loop

The focused multimedia processing includes creation, annotation, adaptation, sharing, and consumption of mobile multimedia data as depicted in Figure 6.1. This mobile multimedia management loop has been conceptualized in Chapter 4 with the operations of semantization and contextualization (cf. Figure 4.3).

As a kind of "snippet" media operations, tagging and storytelling are applied onto effective mobile multimedia management. Tagging and storytelling help users create, manage, and share multimedia. Virtual Campfire also demonstrates multimedia management spanning from Web 2.0 and mobile. Web 2.0 reaches mobile platforms greatly. As some tagging and storytelling operations are still comprehensive and complicated for mobile applications, switching between and complementary use of mobile and Web (2.0) applications are the potential solutions.

6.1.1 Mobile Communities of Virtual Campfire

Mobile users having common interest and practices shape mobile communities [Rhei03]. A *mobile community* is defined by Hillebrand et al. [HGKo02] as a group of people who identify themselves with a common idea or interest and who have the desire to be spontaneous and flexible, participate in communication and get information wireless at any place and any time. According to sociologist Barry Wellman, a mobile community can be defined as a network of interpersonal ties that provides sociability, support, information, a sense of belonging, social identity, and which always connects its members regardless of where they go [Well05]. Thus, mobile communities refer to users who use the same mobile application and have information exchange among themselves. Mobile communities often have more location-based activities than online communities.

Mobile communities have higher requirements on information systems. Mobile communities want to be wireless accessible anywhere at any time, without having to be connected to a stationary computer. As a piece of mobile social software, Virtual Campfire facilitates communication, knowledge-sharing, collaboration, and context awareness among mobile communities. Within the Virtual Campfire scenario, two types of mobile communities are paid attention: cultural heritage communities (CH) and technology enhanced learning communities (TEL).

With establishment of mobile infrastructures worldwide, a lot of changes take place quickly in cultural and social domains. The awareness on cultural heritage and the protection of cultural diversity has become a critical issue within the development discussion of the last years. The international cultural heritage communities as target users require an adapted mobile social software. These communities are a kind of professional communities but multimedia amateurs. They should be adjusted to local needs of heritage preservation in order to bridge cultural and generational gaps. Build-up of such mobile communities can help cultural heritage communities fulfill the cultural heritage management tasks more efficiently.

Figure 6.2 depicts the working manners of mobile CH communities. Cultural heritage communities often use diverse mobile end devices for communication and collaborations among themselves at fieldwork. Use of mobile devices has become simplified with their embedded functionality. Mobile communication cost is being reduced constantly. Mobile technologies have been changing people's working and living ways nowadays. Mobile devices are powerful extensions for human beings to perceive and interact with their physical and virtual environments. Low cost communication can be supported by a wireless mesh network as a backbone [CKTM07]. Various professionals working on a cultural heritage site might be assigned to carry out different tasks at different places in a campaign. They possess the aforementioned features of mobile communities. They need to communicate among themselves. More important, they need to share information with limited energy and low computation capacity devices, even in rural areas where there is sometimes no reliable energy source.

The users may range from national and international visitors who are provided with some basic cultural and ethnographic information while exploring the cultural sites but as well as academic groups such as students or researchers who aim to disseminate specific information on the environment and the history of the place.

Similarly, in the domain of technology enhanced learning, a lot of Web 2.0 based tools including wikis, weblogs, social bookmarks, micro-blogging, etc. provide learners new perspectives and tools to acquire knowledge. Mobile applications and services even enhance mobility and flexibility with context-aware mobile services. Figure 6.3 illustrates how

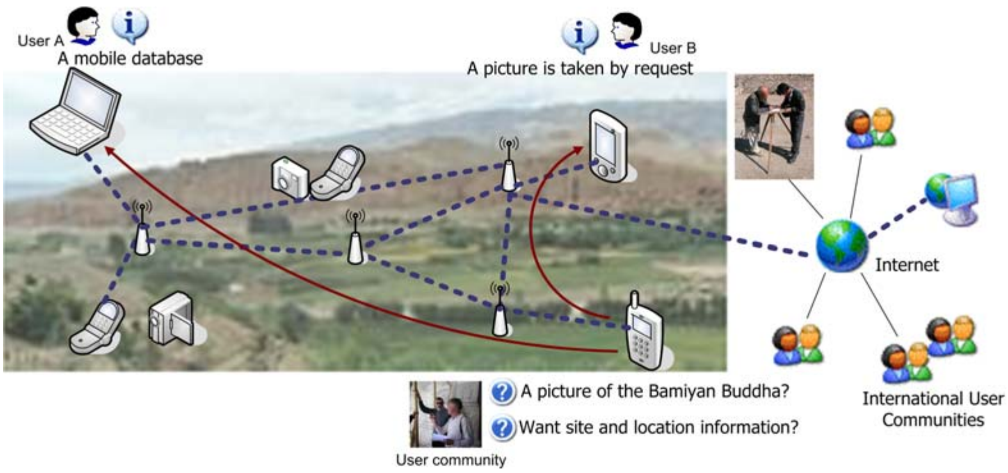

Figure 6.2: Browser-based and mobile community information system for cultural heritage management

mobile communities in technology enhanced learning are supported. Here several concepts in learning are employed including blended learning, situated learning, and personal learning environments. Various mobile multimedia services are needed for knowledge acquisition, creation, search, and sharing. Learning communities require mobility, context awareness with rich semantics by using effective applications on mobile devices.

These two mobile communities are main target communities for Virtual Campfire, because requirements from the communities are able to be collected within several research projects. At the same time, the involved communities ranging from cultural heritage management to learning communities have complex requirements. The prototypes developed within Virtual Campfire target these two mobile communities specifically.

6.1.2 Architecture of Virtual Campfire

As mentioned above, *Virtual Campfire* aims at creation, annotation, adaptation, sharing, and consumption of mobile multimedia data in professional communities with heterogeneous and varying requirements. Virtual Campfire applications have a common data repository and have extensions to mobile devices for ubiquitous knowledge creation and production, search and retrieval, as well as consumption and sharing. A general architecture is required for multimedia management and community management.

Figure 6.4 depicts the main architecture of Virtual Campfire. Hosted on the basic component *Community Engine*, Virtual Campfire provides communities a set of *Context-Aware Services* and *Multimedia Processor Components* to connect to data sources. A large variety of (mobile) interfaces facilitate a rapid design and prototyping of mobile community information systems through standard protocols. Those (mobile) interfaces are combined and used in the Virtual Campfire subsystems introduced below. The services and components

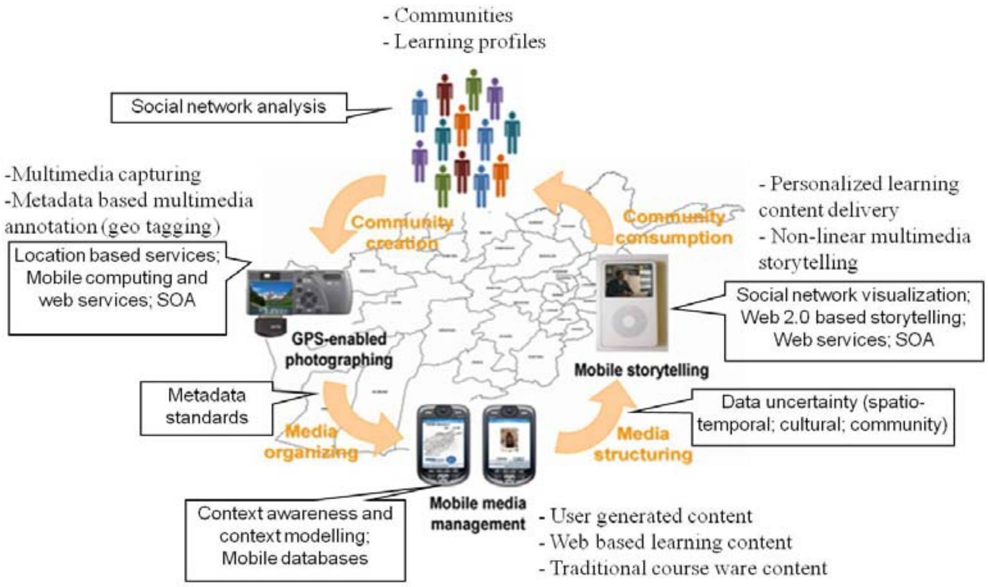

Figure 6.3: A case study of mobile communities for technology enhanced learning

running behind the user interfaces are divided into three layers. On the layer of Community Engine, users and media objects are managed. The Session Manager is implemented to guarantee users' secure access to media objects. The component Data Access connects to heterogeneous data sources. On the layer of Multimedia Processor, all basic processes on multimedia are executed through data exchange with the Community Engine components. On the layer of Context-Aware Services, all necessary services are invoked and deliver functionality to (mobile) interfaces. More services are implemented except these main services listed in this architecture, which are omitted for briefness and more details are given in the derived architecture of each sub-applications later.

The implementation of Virtual Campfire employs the Lightweight Application Server (LAS) [SKJR06]. All Context-Aware Services are implemented as LAS services. Various components of Community Engine and Multimedia Processor Components also run on the LAS server. LAS provides the HTTP and SOAP connectors which make the implementation of client-server communication easy. In addition, the LAS components provide the functionalities such as the connectors to various databases.

This architecture summarizes the implementation of all Virtual Campfire (mobile) sub-applications, which have different foci and usage functionality. Different Virtual Campfire sub-applications extend their own software architecture based on this Virtual Campfire architecture. The successful realization of a number of (mobile) applications listed as follows has proven the concept and validated Virtual Campfire in practices. Each of them is realized on one master thesis research and thus six master theses contribute mainly to the Virtual Campfire scenario.

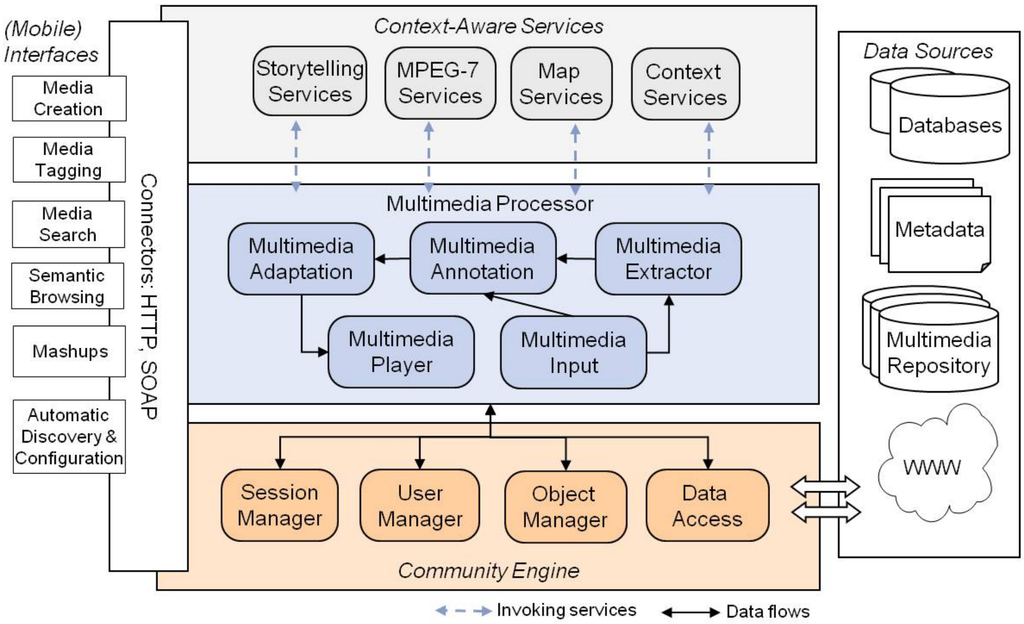

Figure 6.4: Architecture of Virtual Campfire

CAAS (Context-Aware Adaptation Service) is realized to facilitate mobile communities to search for appropriate adaptive multimedia according to context information. Context information includes geospatial, temporal, community, and device context. CAAS focuses on context uncertainty presentation and handling.

ACIS (Afghan Community Information System for Cultural Heritage Management) is a GIS enabled multimedia information system hosting diverse user communities. Cultural heritage management in Afghanistan has its special case, because the national scientific structures and information systems were severely damaged. ACIS facilitates the intergenerational cooperation among communities on an international level. Semantics uncertainty is a severe problem in ACIS. Semantics uncertainty management is conducted through metadata mappings between cultural heritage, multimedia and GIS metadata standards.

SeViAnno (Semantic Video Annotator) is a semantic-enhanced video annotation service to enable collaborative tagging of video frames. Expressiveness of video semantics is enhanced through tagging on objects, agents, concepts, events, time, and places based on MPEG-7. The user interface is simple and comprehensive using Web 2.0 and mashups. Semantics and context uncertainty issues are related and the handling measure is to establish mappings to bridge multimedia semantics and context.

CCPLE (Chinese Classical Poetry Personal Learning Environment) is a personal learning environment especially for Chinese classical poetry (CCP) learning. Various tagging approaches including multi-granular, semantic, community-based, and expert-amateur tagging are applied. Educational games are developed as a useful practice for the communities to

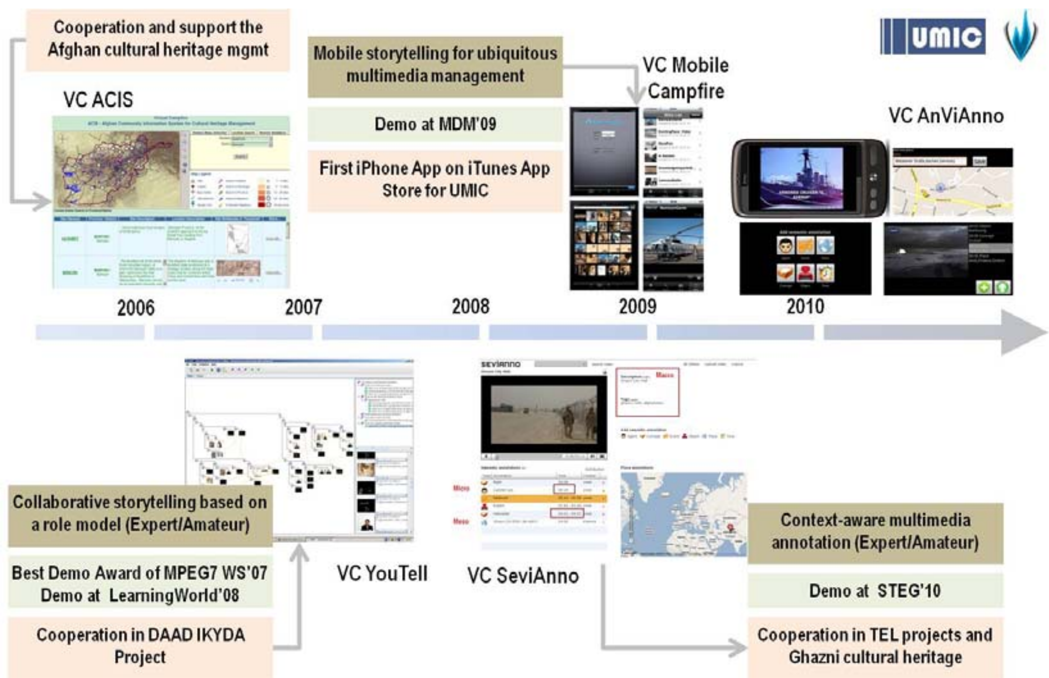

Figure 6.5: Virtual Campfire: timeline of prototype developments

learn CCP with fun. Mainly, semantics uncertainty is handled through various annotation approaches.

YouTell is a multimedia-based non-linear digital storytelling system with the underlying story templates. It contextualizes multimedia artifacts with regard to multimedia semantics and problems addressed by users. Uncertainty issues related to semantics, context, and community are handled through the storytelling approach.

Mobile Campfire is an iPhone application for multimedia creation, tagging, and story sharing. Spatiotemporal context information is captured at real-time photo shooting. Stories composed of images and videos are able to be shared by iPhone users. In this mobile community information system context, semantic, and community uncertainty is handled through both mobile multimedia annotation and storytelling.

All these applications employ the Community Engine and MPEG-7 Services within the Virtual Campfire framework. Other services and (mobile) interfaces are applied according to different communities' requirements. The various architectures of all sub-applications are derived and extended based on the Virtual Campfire main architecture. The main applying domains are cultural science, cultural heritage management, and technology-enhanced learning. Figure 6.5 depicts the timeline of development of various prototypes focusing on mobile for Virtual Campfire. Detailed issues are introduced in the rest of this chapter.

In summary, all these prototypes can be developed rapidly based on the Virtual Campfire architecture. First, the community engine facilitate simple user and community management.

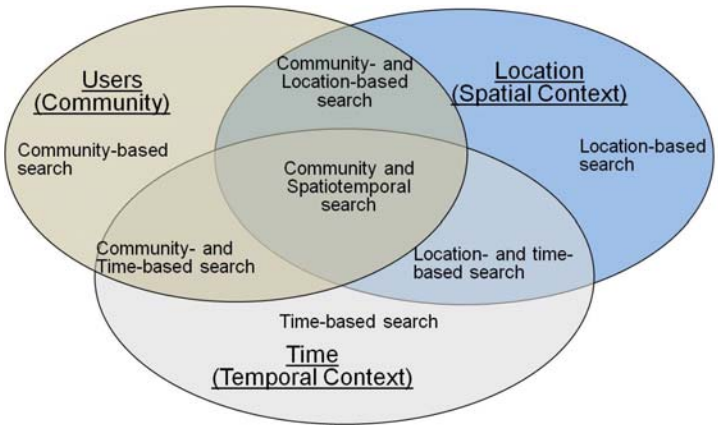

Figure 6.6: Context-aware search functions

Second, the multimedia services are able to be easily used for multimedia semantics and context management, including metadata management. Third, a common data repository is shared for cultural heritage management as well as technology enhanced learning. These domains have high requirements on mobile multimedia management. This common data repository lowers the barriers to develop cultural heritage related applications. Meanwhile, data management services are offered to connect to various heterogeneous data sources.

6.2 Context-aware Mobile Adaptation

Mobile community information systems deal with a large amount of context information collected either from different advanced sensors or from mobile users' input. On the one hand, context modeling is applied to represent context information, while context reasoning is applied to enhance multimedia semantics. On the other hand, mobile device context information is used for multimedia adaptation in order to enhance mobile access of appropriate multimedia. As modeled in Section 4.3, context information is applied to reduce uncertainty aspects and to enhance multimedia query results.

6.2.1 CAAS: The Context-Aware Adaptation Service

Context information of different aspects is rarely taken into account within one information system because of the complexity of context itself. The most useful aspects for context-aware information search are depicted in Figure 6.6. Besides community-based search, time-based search, and location-based search, possible context-aware search should combine each two aspects or all aspects of the spatial, temporal, and community context information.

CAAS deals with various context information and provides adaptive multimedia to mobile communities accordingly. Geospatial and temporal context information is mainly collected by mobile devices. Uncertainty is caused by measure errors. Community context is uncertain due to the dynamic changes of mobile communities, because users' interest on multimedia may change. But meanwhile, additional community context may enhance context reasoning to reduce uncertainty.

Context Reasoning

Context reasoning is normally used to interpret sensor information. For example, in a smart-place system (e.g. an e-Home system), there are a set of sensors which can be used to detect events of the system and to invoke the corresponding inference processes. In CAAS a GPS receiver and the clock of a mobile device receive the location coordinates data and the current time. Therefore, context reasoning according to location information and the current time is important for the system. The localization is still limited to outdoor positioning.

Spatial Reasoning

Location context refers to spatial information such as location coordinates acquired via GPS receivers. Spatial reasoning aims at the logical inference for reasoning over the spatial information of buildings, places, or people. Usually, places and buildings have fixed locations, while people are moving around. It is interesting and useful to figure out relationships between people and location. Whether a user is close to a certain place and what is the distance need be reasoned.

```
(?person spc:IsNearby ?building)
 (?person per:LocatedAt ?loc1),
(?loc1 geo:longitude ?lon1), (?loc1 geo:latitude ?lat1),
(?building spc:hasCoordinates ?loc2),
(?loc2 geo:longitude ?lon2), (?loc2 geo:latitude  ?lat2),
(?loc1 spc:IsNearby ?loc2) .
```

Listing 5: An example of reasoning rules used for spatial reasoning

In general, a space or a building has a certain geometric shape and certain geographical coordinates. A person's movement can also be traced via mobile devices. These coordinates can be used to calculate the distance between two objects. For example, if the values of latitude and longitude of a person and a building are given, the distance can be calculated easily by using Haversine Formula[1].

Listing 5 shows an example of a rule used to configure a rule reasoner to support spatial reasoning. This rule is defined over the SOUPA `space` and `person`. This rule represents such a situation that a `person` is at a location `loc1` with the coordinates `lat1` and `lon1`, and a `building` is located at `loc2` with the coordinates `lat2` and `lon2`. This simple rule draws a conclusion that the `person` is close to the `building` by calculating the distance between `loc1` and `loc2` and comparing it to a constant. Listing 6 shows an

[1] http://en.wikipedia.org/wiki/Haversine_formula

example of the implementation of a spatial reasoner using SPARQL.

```
PREFIX per:  <http://www-users.rwth-aachen.de/min.hou/ont/person#>
PREFIX spc:  <http://pervasive.semanticweb.org/ont/2004/06/space#>
PREFIX geo: <http://pervasive.semanticweb.org/ont/2004/06/geo-measurement#>
PREFIX xsd:  <http://www.w3.org/2001/XMLSchema#>

SELECT ?person ?building

WHERE {
 ?person per:name "userID"
 ?person per:locatedAt ?loc1
  ?loc1 geo:longitude ?lon1
  ?loc1 geo:latitude  ?lat1
 ?building spc:hasCoordinates ?loc2
 ?loc2 geo:longitude ?lon2
 ?loc2 geo:latitude  ?lat2

 FILTER  Distance(?loc1, ?loc2) <= distance}
```

Listing 6: An example of the location reasoning using SPARQL

Temporal Reasoning

Temporal reasoning is used for temporal queries. For instance, if the current time is lunch time, the system assumes that the users prefer to get search results of buildings with the keywords *restaurant*, *fast food*, *eating*, etc.

Community Reasoning

Community reasoning is based on the stored facts of users' personal profiles, contact information, and traveling history or movement. It helps users find acquaintances or friends. Moreover, the common interest is explored via profiles, while common activities are reasoned via users' movement records.

A comprehensive context model is defined for spatial, temporal, and community contexts. Related rules are set for context reasoning. Based on the context model, the Context-Aware Adaptation Service (CAAS) prototype is realized to facilitate context-aware mobile information systems on the client side.

System Architecture Design

For rapid prototyping we employ the Lightweight Application Server (LAS) [SKJR06] as the basic framework, based on the Virtual Campfire architecture. Ontologies using OWL and a media repository with metadata are maintained by a native XML database. Moreover, the main benefit of LAS is that its services can be flexibly extended for specific applications by using the LAS Java APIs. Thus, CAAS is designed and implemented as LAS services within the LAS framework.

CAAS uses Web Service technologies in order to provide easy access to mobile applications on the client side. On the server side, a set of services are provided such as context acquiring,

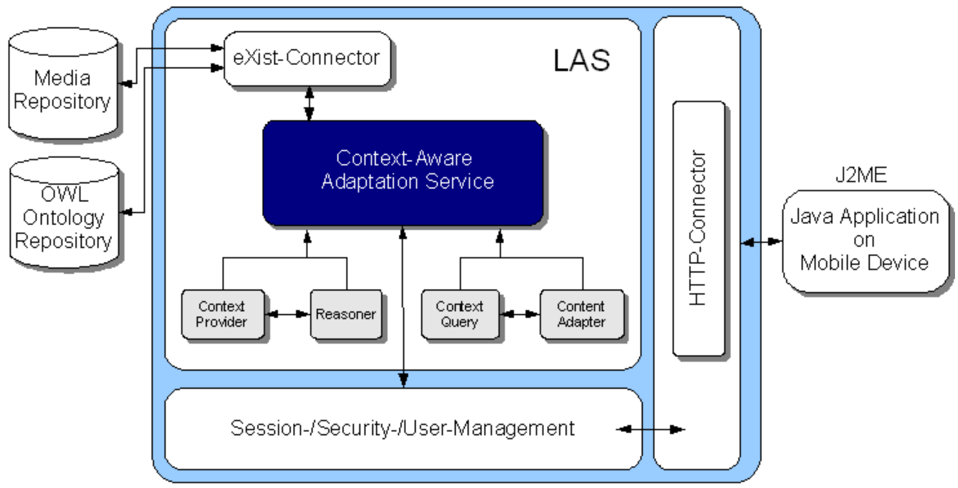

Figure 6.7: The system architecture of CAAS based on LAS [CKHJ08]

context reasoning, and context querying. On the client side, mobile user interfaces can process users' requests and retrieve demanding multimedia results.

Figure 6.7 illustrates the CAAS system architecture with a focus on Context-Aware Adaptation Service for Multimedia. Extensions of LAS components including *ContextProvider*, *Reasoner*, *ContextQuery*, and *ContentAdapter* support the corresponding services on the server side. The access to the media repository and to the ontology repository is realized via the LAS Data Access component. The communication protocol between mobile devices and CAAS is the standard HTTP. The components to facilitate the CAAS service are explained briefly as follows:

- *Ontology Repository* maintains two kinds of ontologies. One is used to describe various types of context and the metadata for the storage structure of the represented knowledge. With it context instances are represented based on existing ontologies and the acquired context information. The other are ontology instances and history contexts for a particular application domain. In short, the ontology repository consists of ontology dimensions to describe context information such as personal status, personal profiles, contacts, users' location and time, as well as location information of buildings etc.

- *Media Repository* contains a collection of multimedia documents such as video, audio, image and text files, as well as the related MPEG-7 metadata. The metadata is at first queried, before adapted variations of the multimedia files are sent to the users on request.

- *Context Provider* represents context information as instances of ontologies using OWL/RDF and then sends them to the *Ontology Repository*, after raw context information is passed over from mobile devices.

- *Reasoner* is a logical inference component for reasoning over the acquired context information. It provides functionalities to interpret context based on the acquired sensor data, to aggregate the context information from ontologies and domain heuristics, to detect and resolve inconsistent context information. Since the raw context information captured initially from mobile devices may be uncertain or may not be useful for the application, the context reasoner translates the low-level context information into a high-level representation. For example, an address of a building is easier to understand than the native GPS coordinates.

- *Context Query* serves as a context consumer. It subscribes context information from the *Ontology Repository* and transforms it from ontologies to the appropriate data structures for further usage.

- *Content Adapter* uses adopted context data and processes the corresponding adaptation, such as location-aware adaptation and/or community-aware adaptation. The adaption requirement depends on the concrete situation. To realize content adaptation, the adaptation service in [KSCa06b] has been employed and partly re-implemented by taking the ontology-based context model into consideration. The temporal, spatial, and spatiotemporal context information is covered, besides the community-aware adaptation.

With these components, CAAS is able to realize services of spatiotemporal and community context-aware multimedia search and adaption. Applications on mobile client devices can employ the CAAS service easily and flexibly. To prove the concept, we have developed and evaluated a mobile culture explorer based on CAAS, which is discussed in the next sections.

Realization of a CAAS Based Mobile Information System

For evaluation and test purpose, a mobile culture explorer was implemented as a CAAS prototype. It employs the CAAS services on the server side and the Java mobile client is installed on the WLAN compliant PDAs. In detail, on mobile devices a Java 2 Micro Edition (J2ME) application enables users to submit users' preferences, device capabilities, current location and changing location, time, and users' requests for adapted cultural information. In other words, users raise their query requests and provide context information from the GUI on the client side to CAAS on the LAS server. Multimedia search results are queried, adapted, and sent to users then. The common issues such as session-, security-, and user-management are dealt with by the internal components of LAS.

The client application provides search services in the form of *Keyword Search* and *Context-aware Search*. To realize the service of *Context-aware Search*, the mobile client must collect information about users' preferences and device preferences via a user interface on the client side. The user preferences include user's name, gender, age, etc. as well as user's interests. User's interest and behavior histories are applied to identify user groups (i.e. communities)

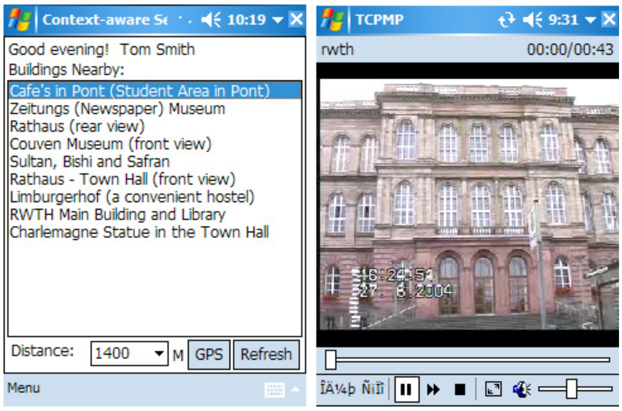

Figure 6.8: A screenshot of *Context-aware Search* and result displaying in a prototype of the culture explorer

by the clustering algorithm. The device preferences refer to physical capacities of devices such as display size, color depth, and so on. They are used for media content adaptation. Both users' and device preferences are raw contextual data and transmitted to the server. On the server, this contextual data is represented as ontologies using OWL/RDF and finally stored in the ontology repository for further use.

In general, *Context-aware Search* provides users information according to users' interest, community's preferences, and spatiotemporal context information. For example, a mobile user is located somewhere in a city. Via *Context-aware Search* the system can display a list of buildings nearby, which can be clicked on to get suitable information displayed in the right form of videos, audios, images or texts. They also fit to the display size of the mobile devices in use. Figure 6.8 illustrates the user interface of the mobile culture explorer in which *Context-aware Search* is performed, the search results are displayed and video clips about the sightseeing are played in a video player.

6.2.2 CAAS Evaluation

The prototype of the mobile culture explorer with the CAAS service has been tested by test users around the city of Aachen. Communities can be classified into sporty people who are interested in the World Equestrian Festival, architects who are interested in historical buildings, pilgrims who are interested in the Cathedral of Charlemagne, historians who are interested in Carolingian Renaissance, as well as those who are interested in spa or wellness etc. Each community has special preferences and interest for different engagement activities. Hence, multimedia about Aachen is suitable for spatiotemporal and community context-aware search and adaptation.

The evaluation was performed on a developing testbed for mobile multimedia community services based on the success model of information systems by Delone and McLean [DeMc03]. This testbed aims at rapid testing and quality evaluation of mobile multimedia community services [RKSp08]. CAAS was tested by a small group of the stereotype communities. At first, the test users were asked to fill out user preferences and hardware preferences via the GUI on their mobile devices. The collected information was transmitted and stored in the central ontology repository. Then the users were able to use the system by preforming *Keyword Search* or *Context-aware Search* from the mobile client. In order to test the quality of the program in terms of reliability, usability, efficiency, maintainability, and portability, the users were asked to make a test report for functionality check. If errors occurred, the error instances were reported for the performance improvement. Only functional tests are not adequate to evaluate a program, because users' subjective opinions are also important issues for information systems development. Therefore, after the testing, users were asked to fill out a usability questionnaire to express their opinions on the mobile culture explorer.

Uncertainty Handling

CAAS applies and evaluates context-aware searches. CAAS aims to deliver mobile users "right" information at "right" time. The experiences with CAAS show the complexity of context information. The context modeling approach is able to represent context and execute context reasoning upon the model. However, the model applied in CAAS is still limited. The more comprehensive the context model is, the preciser results the context-aware queries can obtain. Similarly, the more rules are set up, the better context reasoning can be carried out.

6.3 Applications and Services for Semantic and Context Management

To validate the concepts developed in Chapter 4, three prototypes, ACIS, SeViAnno, and CCPLE are selected with focus on spatio-temporal context capture, tagging approaches to enhancing multimedia semantics management, and tagging and gaming for technology enhanced learning.

6.3.1 ACIS: Mobile Data Management Requirements

Cultural heritage management includes documentation, evaluation of conservation measures, and execution of measures etc. It is a central question for archaeologists, historians, architects, and computer scientists on how to preserve the cultural heritage effectively with the modern technologies.

Cultural heritage damage problem is especially severe in Afghanistan during the civil war and Taliban regime in the past 20 years. Since Afghanistan was on the way to democracy, many organizations around the world have made great effort to make up for the break of cultural heritage management there. Under the appeals and guidance of UNESCO, the International Council on Monuments and Sites (ICOMOS) Germany cooperates with Department of Urban History (Prof. Dr. Michael Jansen), RWTH Aachen University to recover parts of the cultural heritage.

Therefore, along with the practical conservation work, the Department of Urban History had developed an Microsoft Access-based database application for documentation, which cannot fulfill the complex tasks for cultural heritage management. The limitations come from MS access. It does not support multiple users in a network environment. It manages the spatial information of a site or monument in a usual relational database. Multimedia data was managed in a file system without sufficient multimedia metadata management.

Design

The following concepts have been proposed to realize ACIS, namely a multimedia-based geographic community information system for cultural heritage management [KSJ*06a].

Web Community. The concept of a Community of Practice could provide diverse user communities communication channels for intra-generational and inter-generational, as well as intra- and interdisciplinary cooperation. The potential users come from three sectors: government and administration sector such as members of UNESCO, research sector such as students and lecturers of different majors, and preservation sector such as engineers and scientists in the cultural heritage conservation field. All user communities can cooperate together well in a web community environment.

Geographic Information System (GIS). A great amount of information stored in the database pertains to sites and monuments in Afghanistan. Each site or monument has its geographic location information. Textual information alone is not able to represent the spatial information properly and efficiently. Thus, GIS technologies including cartography and spatial queries processing are the central concept of ACIS. In addition, context information can be well used to shape map themes for mobile multimedia management. Table 6.1 lists the role of context management for cultural heritage. Temporal context information is additional listed to describe map themes with timelines.

Multimedia with metadata standards. A great number of photos and audiovisual files are research documents as important as the textual information for researchers in this field. They can belong to cultural objects as sites or monuments. They might also be multimedia files that record a campaign in detail. It has confused researchers for a long time, how to manage and search and retrieve the multimedia information efficiently. Hence, the modern multimedia database technology and metadata standards such as MPEG-7 could be the solution to the enhancement of multimedia information retrieval and exchange.

Cultural heritage management. The cultural heritage object should be represented and described in detail precisely for easy management. Several eminent metadata standards in

Principles	Map themes	Map themes with temporal info
Spatial	Sites of administrative divisions	A site in different periods
	Sites within neighborhoods etc.	Sites of the same periods etc.
Multimedia	Media collections	Characteristics of a site in the history
	Media of a certain type etc.	Media of a site in different periods etc.
Experience	Fieldworks	Fieldworks along the timeline
	Tour routes	Travel blogs etc.
	Personal collections etc.	Personal diary etc.
Community	The distribution of fieldworkers	Community calendar with location info
	The distribution of communities etc.	Travelers statistics etc.

Table 6.1: Context management for cultural heritage management

this field such as standards defined by Getty Institute [ThBo98] are keys to describe the cultural heritage objects properly.

These four concepts together potentially facilitate a community information system to realize the various use scenarios and to meet the requirements discussed with the architects from Department of Urban History at RWTH Aachen University and art historians from Seminar of Oriental Art History at Bonn University. The requirements of ACIS concerned with the aforementioned concepts respectively can be concluded as follows:

In the aspect of community, the input user interface should be as simple as possible. Multi-language-interface and multi-user-interface are supported for users in different countries and for users working in different disciplines. Users can communicate with each other via email and forum service. And the community activities are warranted by users' rights management. In the aspect of GIS, certain search catalogs should be defined for sites and monuments. The query results can also be displayed in maps which are generated dynamically. Graphic spatial query tools need to be developed to support users' interactive queries on the maps. Spatial data should be input into the database with simple mechanisms. In the aspect of multimedia, suitable metadata standards are used to enhance multimedia information search and retrieval. In the aspect of cultural heritage management, thesaurus mediation service could be launched to enhance the interoperability among users who work in different disciplines and use different terminologies.

Multimedia involved in ACIS is diverse:

- Text includes free text documents, structured documents;
- Image includes maps, photographs, paintings, sketches (plan, facade, perspective), posters;

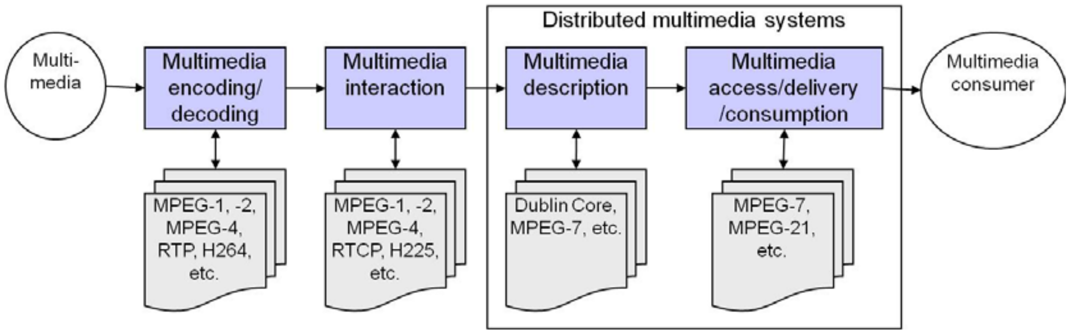

Figure 6.9: The multimedia process model

- Audio includes interviews, radio programs, speeches, lectures;
- Video includes films, documentaries, news clips, lectures;
- (Audio)slide includes collections of images, learning programs(lectures), tutorials;
- 3D-model includes animations, architectural models, etc.

How multimedia reaches consumers via the roles of metadata is depicted in Figure 6.9. The suitable metadata standards are chosen for media description, cultural objects description as well as user communities. They are associated closely with both the cultural heritage objects and multimedia. In addition, users have collections of media and of cultural objects. Hence, there are four types of metadata in ACIS:

- Metadata to describe multimedia is associated with the multimedia itself and with the object as well. The content of multimedia refers to a cultural object usually.
- Metadata to describe objects provides a way to store information about a cultural object.
- Metadata to describe user collections and behaviors concerned with multimedia is used to trace users' access, preference, and interaction of a piece of multimedia.
- Metadata to describe user collections and behaviors concerned with cultural objects is used to trace users' access, preference, and interaction of a cultural object.

Implementation

Based on these aspects, the prototype ACIS is realized to support cultural heritage management in Afghanistan (see Figure 6.10). In the basic tool panel, the map can be zoomed in and zoomed out. The map image size can also be modified according to the zooming scale.

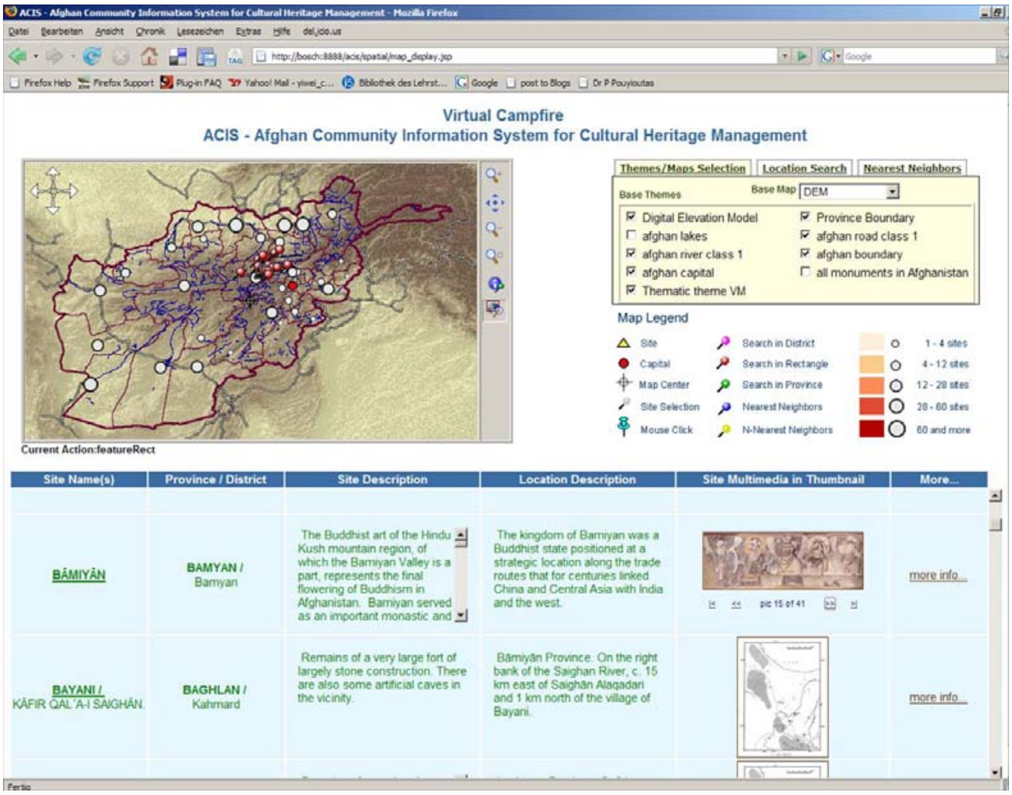

Figure 6.10: The screenshot of ACIS

So the map panel has been implemented with a scroll bar to display the other part of the map. The center of the map can be set by giving the geographic information. The menu of the theme manager lets user select predefined themes, e.g. province boundary, district boundary, main cities, main roads, main rivers, and lakes.

The cultural heritage object's name can be shown in a label, if the users move the mouse on a site or a monument in the map. If users click a site in the map, the description of the site on the interacted point can be displayed in the information panel. Meanwhile, the multimedia files related to this site can be played as thumbnails in the multimedia panel.

The spatial search panel provides different graphic tools for the users to make some spatial queries. All cultural objects that are allowed to be viewed by users as public information can be displayed on the map, when users click the button "All Monuments". The additional spatial search tools implemented in the prototype of ACIS are as follows:

- Search a site (cultural object) with a certain site name;
- Search all sites (cultural objects) in a certain province;
- Search all sites (cultural objects) within a rectangle drawn by users;

- Search all sites (cultural objects) within a certain distance restriction, with reference to a center point clicked by users;
- Search the next *n* sites (cultural objects) in the neighborhood with reference to a center point clicked by users.

Then the spatial query results are listed in the information panel. A single site can be selected and is marked in the map with another marker. Its related multimedia data including videos and images can also be displayed in the multimedia panel in a new window. In this way, location information, site description, and multimedia information are well organized and displayed. The multimedia data collected is applied in all other Virtual Campfire prototypes. Many videos recording interviews to experts are valuable for many cultural heritage managers. The Web-based ACIS is also accessible in the web browsers on smartphones.

Evaluation

The evaluation was carried out through polls. Several user communities have taken part in the ACIS evaluation. They are art historians at Seminar for Oriental Art History of Bonn University, architects of Department of Urban History, students at Department of Information Systems and Database Technology of RWTH Aachen University, students at Department of Traffic Engineering of Shanghai Tongji University, and Dr. R. D. Spanta, who is now a consultant of President of Afghanistan and worked for Third World Forum Aachen. In addition, both Prof. Dr. M. Jansen of Department of Urban History and Prof. PhD. S. Zheng of Institute of Architecture and Urban Space of Tongji University gave an interview. Furthermore, an on-site evaluation was also conducted by architect G. Toubekis in Kabul, Afghanistan.

The collected feedback proves that the data quality is good and the system quality of ACIS is stable. The requirements with high priorities have been fulfilled. ACIS overcomes the limitations of the MS Access-based application and can be well applied in practice for the cultural heritage management in Afghanistan by various user communities.

In the evaluation of information quality issue, the application in cultural heritage management is greatly dependent on information that it can impart. The information quality of ACIS is evaluated as interesting and instructive. However, it is not precise enough due to the limitation of the existing data. The geospatial information of sites and monuments stored in MS Access database are fairly rough. Its accuracy only reaches to the unit of minute of arc. One minute of arc in latitude or longitude equals approximately 1.8 kilometer on the earth. Some recent fieldwork that was conducted by Georgios Toubekis is able to provide much more precise geospatial information about monuments and sites. With those information ACIS will be able to provide more valuable information.

Moreover, the quality of multimedia is of great importance for researchers. In ACIS it keeps the quality of multimedia files as they were in the existing application. Furthermore, the meta information of some multimedia is not comprehensive enough. Due to the mixed status of the original multimedia descriptions, most of the information cannot be extracted automatically and input into the structured XML file using the MPEG-7 standard.

The on-going on-site fieldwork further shows that cultural heritage data embraces much rich semantic and context information. For example in Bamiyan, 26 monuments and sites are surveyed by researchers at the Department of Urban History of RWTH Aachen University in the summer of 2005 [CKS*06]. This information comprises name of surveyors, date, and further:

- Basic information: village/settlement, house no., coordinates, house name, function, inhabited/abandoned, type, access, owner
- Characteristics of site: description, description of context, component/material (wall, surfaces int./ext., roof, doors/windows, decoration), condition
- History: original function, date of construction, transformations, anecdotal accounts, published accounts, previous surveys
- Relevance: historical, urban, architectural, technical
- Photo documentation: film, photo no., sketch and photo position plan (date, surveyor, settlement/village, monument, and film no.)

Uncertainty Handling

Integration of spatial search panels on maps enables users to carry out spatial queries more precisely. In order to improve the metadata quality, the annotation category using Dublin Core metadata standard needs to be organized and explained in a better way. Although ACIS presents the link to the core elements set of Dublin Core, a direct help or explanation of the categories needs to be integrated. This also shows the importance to establish mappings of different metadata standards across application domains.

The continuous execution of the operations semantization and contextualization can improve semantic richness and precision. ACIS applies advanced GIS technologies to make good use of location context information. Various metadata standards across GIS, cultural heritage management and multimedia are applied for semantics enhancement.

Users need to login and have been assigned with a pre-defined role. The community-based role model is not explicit designed. But the governors, administrators, experts, locales may play different roles in knowledge and information processing [CKJa10].

6.3.2 SeViAnno: Various Tagging Approaches

SeViAnno is a semantic-enhanced video annotation service for video frame-based collaborative tagging. SeViAnno aims to deliver a guideline for interactive semantization of multimedia using RIA in the field of cultural heritage. Together with the Center for Documentation and Conservation at RWTH Aachen University, problems are discussed and requirements are analyzed to elicit functional and non-functional requirements. Semantic Video Annotator (SeViAnno) validates the concept of various tagging approaches to enhance multimedia semantics and context [CRJ*10].

Requirements Analysis

The requirements analysis consists of several steps. At the first step of the requirements analysis, a paper prototype [Snyd03] has been created (see Figure 6.11) prior to first implementation in order to avoid major interface flaws. Results are considered for both the implementation and the features. The paper prototype consists of printed elements and Post-it's. Post-it's are used to simulate interactivity. The prototype has been tested with 30 persons (11-72 years old) with different experience backgrounds of technology usage.

First, it is tested whether the actions caused by clicking buttons are clearly predictable and do not have any surprising effects. The concept of tags is especially unclear to users without any computer background. The Google Map integration is very well received and therefore most people can directly understand the underlying concept of having location as one type of semantic annotation.

At the second phase, the test is about whether the test users are able to solve a given task (e.g. find the annotation "coin"). At this phase the outcome is that a clear terminology and as few mouse clicks as possible help to increase the usability and understandability. Too many sub menus may frustrate users and lead to a decrease of motivation.

At the third phase, different icons are tested to represent different semantic tags based on MPEG-7 semantic base types. The users are provided with printed versions of the icons which they have to sort in a sorting field. As a result we are able to evaluate the clearness of the icons. The most difficult icon to recognize is the tag icon.

All test results are documented on a predefined form to simplify the evaluation. The last part of the evaluation form includes some spaces for generic comments. Many users mention to include a timeline for the time specific annotations to visualize these base types in a better way, like it is already done with the place base types on a map. Although paper prototyping is a time consuming process, it has proven to be excellent for increasing usability and for avoiding major flaws before the actual implementation.

Based on the use case depicted in Figure 6.12, analysis of current products and the paper prototype, the SeViAnno web service should include the following features:

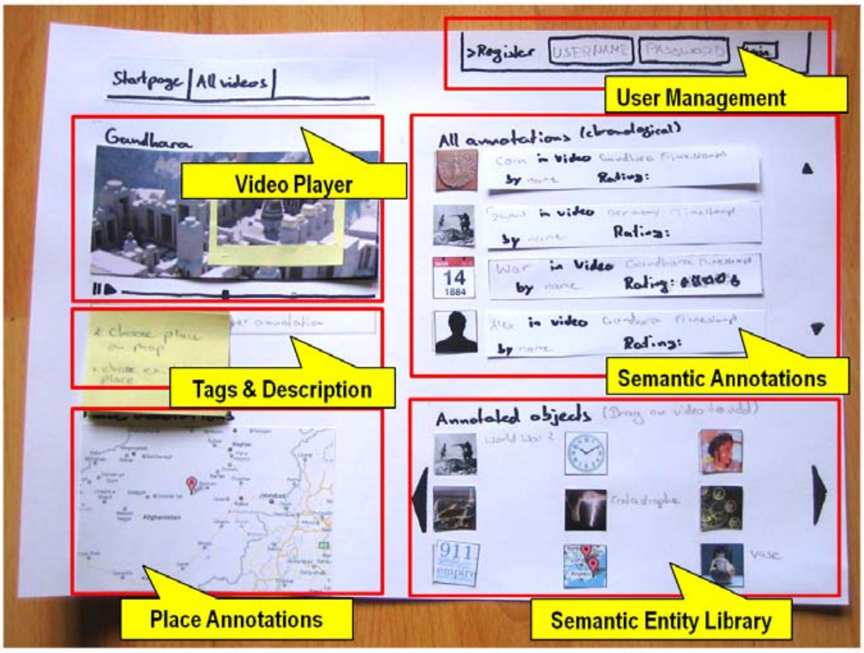

Figure 6.11: Paper Prototype for SeViAnno

The *annotation* functionality should be included, and it should be possible to create, to edit, and to delete annotations. The most important part is creating annotations. Therefore, adding a description and keywords for the overall video must be supported. A much more important function is the ability to separate videos into sequences and adding keywords or certain semantic types. Usual text input should be supported. Furthermore, optimized UI elements for the input of certain semantic tag types should be supported to achieve a better usability. For instance, adding place information such as longitude and latitude can be supported by selecting a location on a map. Pre-entered annotations such as historic persons can be shown in a list and can be added by drag & drop. An editing mode can be accessed by clicking on the "edit" button. Terminology support can be included by adding a tool tip box.

The *display* function supports to show existing annotations in different ways:

(a) Overlaying annotations on the video player;

(b) A list of all annotations: if a user clicks on an annotation, the video seeks to the corresponding position.

(c) Place information can be indicated with markers on a map (e.g. Google Maps). A click on a mark should have the same behavior as in the list.

(d) A timeline for time annotation.

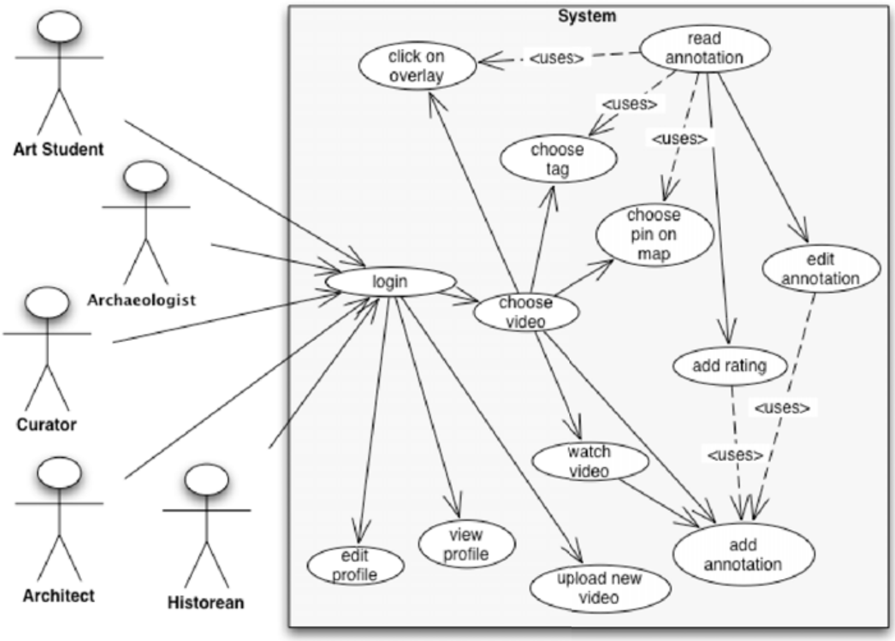

Figure 6.12: The use cases diagram of SeViAnno

User management includes creating, editing, and deleting of user profiles. The most important functions are registration and login. It should be possible to differentiate users by the community they belong to. To support the communities of practice, a rating system for annotations is considered useful. Every user gets an overall rating and people begin to compete to get better ratings than the other users.

Video Upload should enable users to upload video files to the service. Already uploaded video files can be annotated by every user belonging to the corresponding community. Various file formats should not be any barrier and therefore the web service needs to be capable of server-side video encoding.

Additional potential features are a search function, object tracking, and object tracing. Furthermore, non-functional requirements are analyzed. Usability provides an easy and efficient way of interaction with the web application. Therefore, the needs of the main users should be regarded. To find out the users' needs, user tests can be conducted and evaluated. Heuristics like the design guidelines by Nielsen [Niel00] can be additionally applied, e.g. learn ability and user satisfaction. McLaughlin and Skinner [McSk00] reduce usability to six basic components:

(a) Checkability: System checks or allows checking to ensure that correct information is going in and out.

(b) Confidence: Users have confidence in using the system and in their being able to use the system.

(c) Control: Users have control over the system and especially over the data streams.

(d) Ease of Use: It is very simple to use the system.

(e) Speed: The system can be used fast.

(f) Understanding: The system and especially the output are understandable.

In SeViAnno, simplicity can be achieved by reducing the amount of needed clicks to perform a task. Understandability can be increased by using clear terminology and visual help such as with tool tips [Niel00]. Portability, the platform independence, is required to solve problems with different operating systems or devices used by members of the same community. This can be achieved by using Adobe Flex or other RIA technologies. Robustness means that services should be reliable and avoid a high amount of failures. Especially possible false user actions should have no negative influence on the application. Speed requires that interaction should be fluent and not annoying. Working with video files in a slow way can become very annoying and should therefore be avoided. Mobility is a very important aspect of future development of web applications. Developers should prepare their applications for mobile use.

Semantization and Interactivity

The main elements of semantic information in videos dealing with immobile cultural heritage are persons, places, time, buildings and objects. Therefore, the most important semantic base types are the following types:

Agent describes persons by their full name and an optional email address. *Object* is a very generic term and should be used for daily objects, artifacts, historic objects, etc. Both the name and its description are stored. *Concept* is some abstract information and is formed in the mind like a thought or a notion, in contrast to *Object*. For example, culture or religion can be considered as concepts. *Event* can be stored using the name, date, and location. Its location is saved by longitude and latitude. An example for an event is a battle during World War II. To achieve unity among event names, a predefined list can be used. *Place* describes the location of the action or the location which is shown in the video. It is stored with a name, longitude and latitude. *Time* describes a date. It can describe the date of an action or an event and is stored with a name, duration, and date.

In addition to the semantic tags, it should be possible to add simple keywords and descriptions to video segments. For the beginning, the chosen base types are sufficient for use in the context of cultural heritage. Nevertheless, it is possible to construct the complete type hierarchies in MPEG-7, but it is questionable whether this would not contradict to the requirement for simplicity.

A first idea for interactivity realization is to show all existing annotations as a tag cloud [YMON08]. Small icons/images should help identify the type of the annotation. It should be possible to drag an annotation of the tag cloud and drop it on the video in order to simplify the annotation process. Then a dialog should appear to define the end of the sequence and it should reuse the semantic base types. A list of all existing annotations should be available, too. This improves the overview and makes it possible to navigate through the video using this list. The sorting of the list should be changeable. Annotations containing place information should be shown on a map indicated by markers. Hovering on a marker delivers information about name, time point, and duration. A click on the markers enables navigation in the video by using the place annotations. To implement this functionality, the mashup concept is applicable using either Microsoft Virtual Earth or Google Maps. The map is used to simplify adding place information.

Architecture

The SeViAnno architecture as depicted in Figure 6.13 is based on the Virtual Campfire architecture. The classical 3-tier model diagram gives a better overview of the extensions of MPEG-7 Services, which are core services to make the best of SeViAnno. The *client tier* constitutes the SeViAnno front-end and consists of the main elements User, Video Player, and Annotation. The Video Player provides the possibility to watch, change, and upload videos. The User element is responsible for user management (e.g. registration, creation and viewing profile). The Annotation element is responsible for the biggest part of the client tier. It contains the whole interface for adding, editing, and viewing annotations. Parts of the user interface are Map, Timeline, View and Edit.

The *business tier* provides all services, which are used by the client tier. Video management is mostly done by Flex components. Annotation management is realized by LAS services. Especially the MPEG-7 Semantic Base Type Service, MPEG-7 Multimedia Content Service, and User Manager Service are used. To allow video segmenting it is necessary to extend the MPEG-7 Multimedia Content Service with additional methods.

The *resource tier* consists of elements which are mainly existent at the institute's local infrastructure. MPEG-7 data and security-relevant data are stored in XML databases. In order to store, encode, and stream video files, Wowza Media Server 2 with RTMP protocol supports to stream videos to the flash video player.

Implementation

The SeViAnno prototype has been implemented based on the previous requirements analysis. The used software, data sets, and problems occurring at the development are explained in details.

The most important part of the Flex implementation is the complete annotation functionality which includes creation, display, and editing. All annotations are shown in a list sortable by

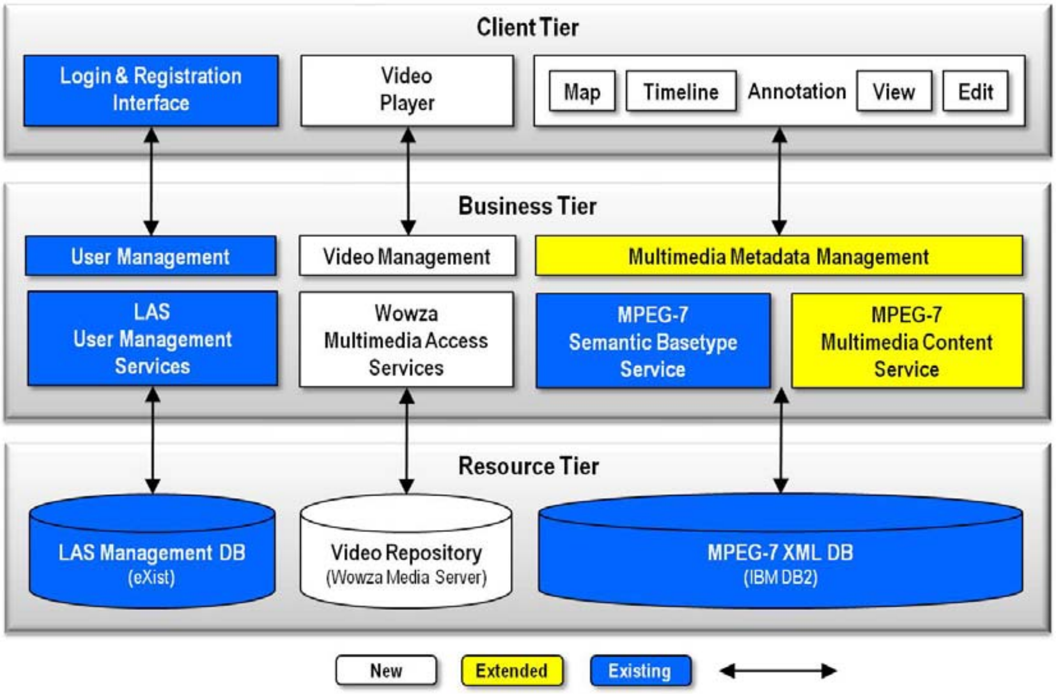

Figure 6.13: The SeViAnno architecture

type, time point or alphabetically. Place annotations are shown on the lower right side in the integrated Google Map. Thereby every annotation is indicated by a marker. By clicking on a marker or an element in the list, the video is played to the corresponding time point directly. The description and keywords are displayed on the upper right side of the application (see Figure 6.14).

The second aspect is the creation of annotations. Annotations are added by a simple click on the name of the needed base type along with the additional input of a text description. Adding a place is done in the Google Maps part of the interface either by specifying the name of the searched location in a search field or by directly clicking on a point on the map. Longitude and latitude are provided automatically.

The client is realized using Adobe Flex/Flash 4 with the advantage to be platform independent and to be prevalent on the market (except support from Apple mobile devices). All products developed in Flex are accessible via a standard Flash plug-in. Furthermore, Flex is a very sophisticated framework with many libraries. For instance, the video player has existed already and only needs minor adjustments. It is the leading technology for online video applications. The Flash Builder 4 IDE is based on Eclipse and does not need any adaptation before use.

Since the Lightweight Application Server (LAS) has already provided a range of operations on MPEG-7 descriptions including their persistence in a native XML database, developers

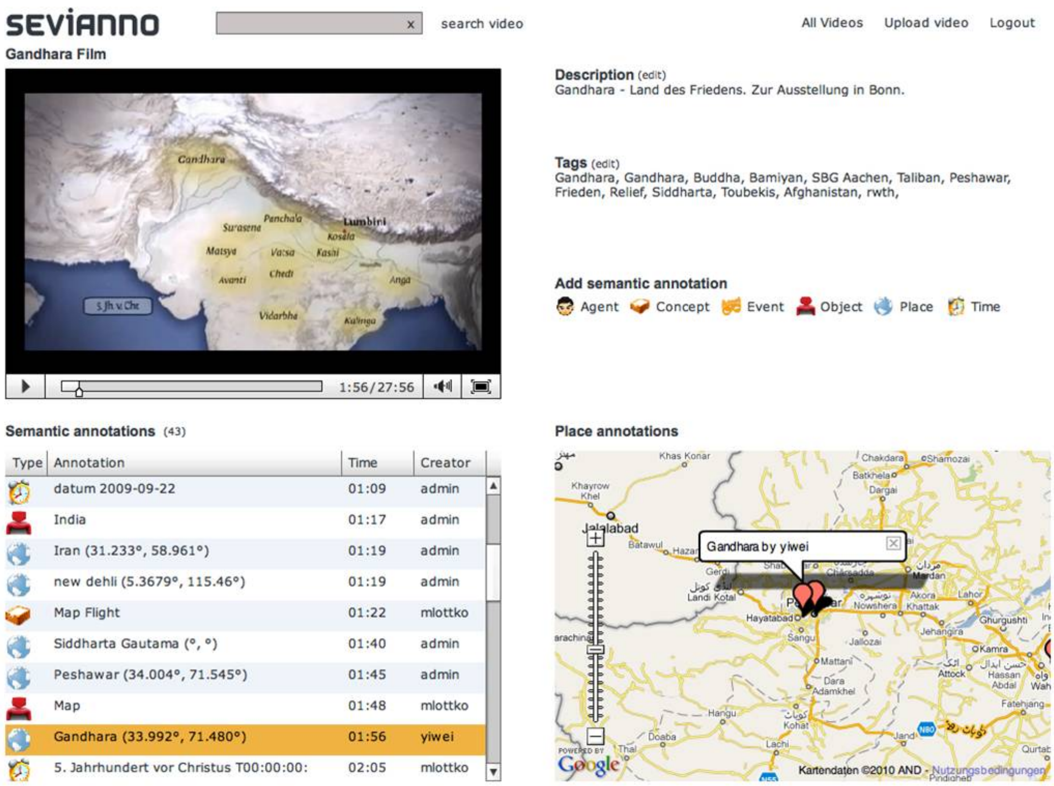

Figure 6.14: The screenshot of the SeViAnno Web interface

can mainly concentrate on client side development of SeViAnno. Communication for RMI is realized using a LAS connector for the HTTP protocol. A set of LAS core services have been already realized for the management of users, communities, and access control; and for a website for LAS registration.

Several multimedia services are employed. The *MPEG-7 Semantic Base Type Service* is designed for the management and persistence of MPEG-7 semantic base types, which can serve as semantic tags assigned to multimedia or segments. The *MPEG-7 Multimedia Content Service* is designed for annotations of complete multimedia files such as images and videos. Those services towards the segmentation of videos employing the Audio Visual Segment Temporal Decomposition Type of the MPEG-7 standard have been added to the existing multimedia services. The Audio Visual Segment Type is now used to add the semantic references of the base types corresponding to the video segments. To save the time point and the duration of the segment the MPEG-7 Media Time type as a description tool has been employed. The extension of the service has been realized using XMLBeans, which is used in most of the LAS services. The LAS framework helps solve the problems of impreciseness of intuitive annotation tools.

Figure 6.15 shows the media description in MPEG-7. Each video file has a main metadata file in MPEG-7. This master MPEG-7 file is linked to its semantic base type sub files in


```
<urn:SemanticBase xmlns="urn:mpeg:mpeg7:schema:2004"
xsi:type="urn:SemanticPlaceType"
id="SemanticPlaceType_admin20090924111550802"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" x
mlns:urn="urn:mpeg:mpeg7:schema:2004">
  <urn:Label>
    <urn:Name>Pakistan</urn:Name>
    <urn:Definition>empty</urn:Definition>
  </urn:Label>
  <urn:Place>
    <urn:GeographicPosition>
      <urn:Point altitude="0.0" latitude="30.98003963984624"
longitude="67.93886600000002"/>
    </urn:GeographicPosition>
  </urn:Place>
</urn:SemanticBase>]]>
```

```
  <urn:TemporalDecomposition>
    <AudioVisualSegment xmlns="urn:mpeg:mpeg7:schema:2004">
      <urn:Semantic>
        <urn:Label/>
        <urn:SemanticBaseRef href="http://www-i5.informatik.rwth-aachen.de/las/db/xml?declare namespace
mpeg7=
&quot;urn:mpeg:mpeg7:schema:2004&quot;;/mpeg7:Mpeg7/mpeg7:Description/mpeg7:Semantics/mpeg7:
SemanticBase[@id=&quot;SemanticPlaceType_admin20090924111550802&quot;]#mpeg7-semanticbase"/>
      </urn:Semantic>
      <urn:MediaTime>
        <urn:MediaTimePoint>T00:00:48:000F1000+01:00</urn:MediaTimePoint>
      </urn:MediaTime>
    </AudioVisualSegment>
...
...
```


Figure 6.15: Example of media description created by SeViAnno

MPEG-7. This file structure enhances the flexibility for master MPEG-7 files which can be linked to as many as sub metadata files. Nevertheless, the sub metadata files can be reused to describe different multimedia files.

In order to be able to use the video files for streaming to the Flash application, it is necessary to convert a file, if it is not encoded in the H.264 codec. Converting the video file is done by FFMPEG[2], a free software used on most platforms to record and convert videos. In addition, it supports all important video codecs. Then it is copied to the Wowza Media Server 2, where it is streamed using the Adobe RTMP protocol. Wowza Media Server 2 allows us to use the same video files for different services, as it supports many streaming protocols, e.g. Adobe RTMP, Apple HTTP Streaming, Microsoft Smooth Streaming, RTSP/RTP and the MPEG-2 Transport Protocol. Four different video files on the topic of the Gandhara culture are used for testing, as the Aachen Center for Documentation and Conservation (ACDC) has presented an exhibition about this culture.

Evaluation

Two main evaluation phases have been carried out. The first one is the aforementioned paper prototype, and the second phase includes a test of the SeViAnno software prototype. The software prototype has been evaluated in two different ways. During the tests all session

[2]http://www.ffmpeg.org

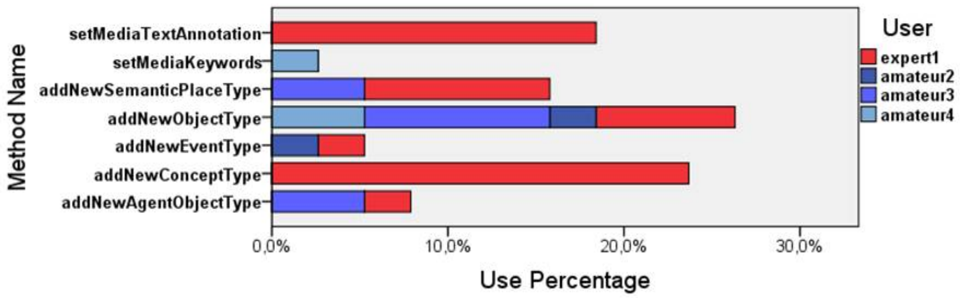

Figure 6.16: SeViAnno system usage monitoring with MobSOS

times and method calls have been registered by MobSOS [RKSp08], thereby enabling us to find the most frequently used features. Besides analyzing user data, the surveys have also been conducted to evaluate the usability of the SeViAnno application.

Monitored by MobSOS, during a three-day testing phase over 1000 method calls were executed. Most calls were made to receive data such as keywords, semantic annotations, and full-text descriptions. This high percentage can be explained as all semantic tags are retrieved again after adding an annotation. 100 method calls represented the creation of new information for the four video files. One third (1/3) was called to add keywords. 73 calls were caused by semantic tags, whereby place was responsible for 31 calls. This can be explained by the content of the videos, as they contain a lot of maps shown in the video and change locations very often. Nevertheless, the very intuitive use of the map also plays a role. The prototype was tested by about ten persons, the majority of whom had a computer science background. Figure 6.16 depicts the distribution of MPEG-7 service method calls among the respective users.

In the user surveys we had the intention to compare the prototype with VideoANT and M-OntoMat Annotizer (cf. Section 4.5.1). Every test user had the possibility to evaluate every tool as long as he/she wanted to. The first tool was VideoANT, then M-OntoMat-Annotizer and the last one was the SeViAnno prototype. Results of the evaluation show that SeViAnno is regarded as being only a little less usable than VideoANT, but much better to use than M-OntoMat-Annotizer. SeViAnno is also regarded as much more precise than VideoANT regarding metadata, but a little bit less precise than M-OntoMat-Annotizer.

To conclude, both conducted user tests and evaluations of the prototype highly recommend to improve usability. A paper prototype provides an early indication of design flaws and missing features. It can avoid a complete reinvention of an already implemented user interfaces to save a lot of time reorganizing functions or adding essential functions during later development phases. Software prototypes deliver a good overview of already sophisticated functions and other functions, which still need refinements. It can also deliver ideas for future development and help determine whether goals are reached.

Uncertainty Handling

On the semantics uncertainty handling level, tagging activities take place with various annotation approaches. Granularity tagging approach is applied to tag video at a time point, within a time period, and as a whole. Tags at different levels work together to reduce data uncertainty. Although the tags have been collected and stored in the databases, more data analysis work needs to be carried out in future. Especially, social network analysis can be applied to cluster the tags of multimedia items. The MPEG-7 metadata-based tags are employed widely in SeViAnno, which enhances the semantic precision and richness. Currently only a set of semantic base types are in use and the number still needs to be enlarged.

On the community uncertainty handling level, requirements analysis, design, and realization of user interfaces in SeViAnno help users express and use the right operations on multimedia in order to reduce the uncertainty of community operations greatly.

6.3.3 CCPLE: Tagging Classical Chinese Poetry for Learning

Poetry makes people think and does not have an instantaneous application field, as many essays do. Classical Chinese poetry (CCP) has rich semantic information. Thus, learning CCP is a good case study to apply various tagging approaches. Hence, Chinese poetry is not well spread to the rest of the world, compared to many master works of classical Chinese text, e.g. Confucius or Lao-Tse. In ancient China, classical Chinese poetry was the main learning content for students in private schools, the so-called Chinese Schools, which was the only location to hold learning communities.

Classical Chinese Poetry Learner Communities

As a crucial part of Chinese literature, classical Chinese poetry (CCP) is a valuable deposit of knowledge and civilization over 2000 years and reflects the versatile of history, society, economics, philosophy, and languages. Thus, it has great impacts on all Chinese-speaking regions worldwide and provides important learning and research resources. Reciting CCP has been ever part of Chinese language learning [Seat06]. This conventional poetry learning method has been used at all Chinese classes on all Chinese school levels. Poetry is collective wisdom and knowledge of mankind over a long history. Classical Chinese poetry is an important sub category of classical Chinese text and contributes greatly to Chinese literature. It is featured with certain ending syllable rhymes and consists of at least four lines of three characters, five characters or seven characters (cf. Figure 6.17 bottom-right).

Several significant issues can be identified in current CCP. Firstly, the learner community has been widened and increased in versatility. Not only Chinese children learners but also Chinese adults and elderly people, foreigners, sinologists, etc. begin to show interest in learning CCP. Their goals among others are to use CCP as a vehicle for Chinese language training, to raise Chinese culture awareness, and to keep Chinese traditions alive. Secondly, CCP has been losing its attractiveness in Chinese-speaking communities worldwide in comparison to a hundred years ago. The reasons are manifold again. For example, reciting CCP has been considered as a tedious learning task for children, compared to playing video games. Thirdly, CCP is not well spread outside Chinese-speaking regions despite its offerings of substantial Chinese knowledge over a long history. The learning barriers are high due to the difficulty of the Chinese language itself as well as missing access channels. Finally, modern information technologies have not been broadly applied for CCP. In contrast, such ancient knowledge or culture is also raising new problems and conflicts by the rapid development of technologies. Technologies are shaping the interactions of communities in a way which may be conflicting with the traditional knowledge itself. Learning with new technologies may also deepen the understanding of and re-vitalize old knowledge for our times.

Hence, it is challenging to discover the potentials of modern information technologies for preserving and developing traditional knowledge such as poetry. Research questions are addressed such as: how can information technologies find the balance between traditional knowledge even from ancient times and a great amount of digital media and information?

In recent years, information technologies have been applied to provide learners new means of accessing and learning CCP via Web sites, videos (e.g. youTube), television, radio, or some digital libraries. This shows that learners have great demands on free and worldwide access to a large amount of CCP learning content. It aims to lower barriers of access to traditional knowledge and to make poetry learning full of fun without much learning difficulties. A model of CCP is the basis for the design and realization of the personal learning environment (PLE) for learning CCP across learner communities.

Learner communities learn CCP with different aims and often have not the same educational background. Their expertise may range from novice knowledge, such as children and foreigners, to experts, such as students and sinologists. Learners are distributed all over the world. A centralized learning environment cannot satisfy the requirements for CCP knowledge representation distribution in much media.

We define here four levels of expertise in CCP. The first level describes the novices and the foreigners who know a little Chinese and want to improve it by learning CCP, or do not know Chinese at all, but have interest in learning Chinese. The second level contains the people who have recited some CCP but do not understand the content of them, such as younger children. The third level contains the students who have learned much about CCP and grasped some CCP spirits or artistic concepts behind the poetry, even the Chinese history and culture behind CCP. The forth level is the expert level. Experts research on CCP as their profession or as their hobby, e.g. sinologists. How to integrate the four groups in the CCP knowledge domain with CoP principle and how to spread the knowledge in the distributed community is a great challenge.

Within a PLE it is needed to identify these learners with different knowledge degrees. In

CoP there is a clear distinction between masters and apprentices. The apprentice learns from the master by observation mainly. Here, in a self-regulated learning situation learners on different levels must be able to recognize each other even in a virtual setting. It is possible for learners on different levels to approach more knowledgeable learners to get more knowledge according to their learning goals. In the PLE any learners can manage their own learning goals in such a way. On the Web 2.0 established practices are linking of Web resources or commenting on existing content. Other practices include rating of content and learners, visualization of content metadata such as tag clouds (folksonomies) and recommendations.

The research tackles the aforementioned problems through systematical modeling, design and realization of a Web-based CCPLE. A layer model is proposed to capture features of CCP learning on the macro, meso and micro scales. This generic model facilitates CCP exchange between different platforms.

A Model for Classical Chinese Poetry (CCP)

The learning activities of users with different learning profiles are different. Usually learners learn CCP through repeating a word or repeating a sentence, from a single word to a single sentence, to a single paragraph, and to a whole poem.

CCP stored in the learning content repository has several important consisting parts: opuscule, feature, author, and dynasty. An *opuscule* is produced by the members of the CCP community and link is submitted by the learners to CCP. Commenting provides the key interaction in the CCP community, in the moment. The *feature* is the style of poetry. An *author* is the name of the poet. A *dynasty* stands for the period of the poetry or the poet living in. According to the learning process, an abstract model for CCP is a three scale model consisting of micro, meso and macro scales. Metadata of classical Chinese poetry includes poem title, author (poet), dynasty, feature ranging from 3-character to 7-character or tune name etc. Metadata can also be given in many languages besides Chinese. CCP can be modeled in XML with tags like <poetry>, <paragraph>, <sentence>, and <character> (see Figure 6.17 bottom-right).

A poem can be modeled as an XML schema. Figure 6.17 models a graphical representation of an XML document tree. On the micro scale a poem is a collection of single Chinese characters. Micro content consists of character units. On the meso scale a poem is decomposed into several short sentences ended by a unique punctuation. Meso content consists of sentence units. On the macro scale a poem is decomposed into paragraphs as a certain block (20% or 50%) of the poem or even the poem as a whole. Macro content consists of paragraph units. The content scales fulfill the following rule:

Micro scale content $\subseteq$ Meso scale content $\subseteq$ Macro scale content

According to the aforementioned poetry model, operations can be defined on three levels correspondingly: paragraph permutation (macro operations), sentence permutation (meso

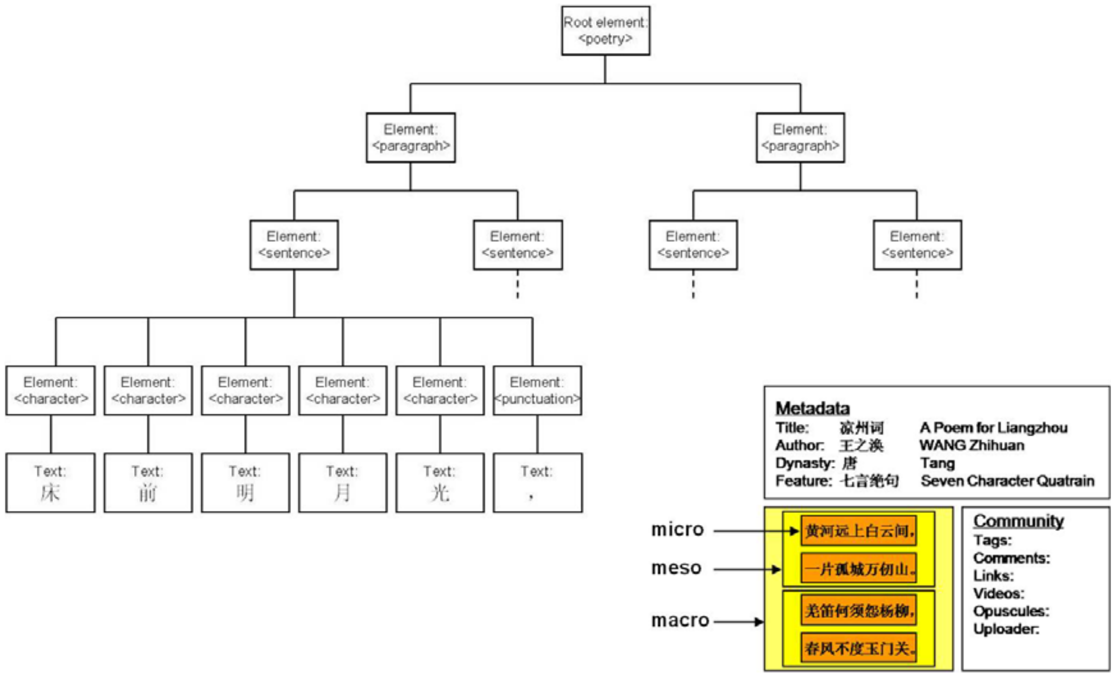

Figure 6.17: The XML model of CCP

operations), and character permutation (micro operations). The operations have the following relationship among themselves. This is verse vice to the aforementioned content scale.

Micro operations $\subseteq$ Meso operations $\subseteq$ Macro operations

Learners can select a content level at first. On the macro scale, macro operations can be performed, while micro operations are performed on the micro scale correspondingly. With this flexible combination of content scales and operation scales, users can select learning content according to their learning profiles and preferences. Learning difficulty is raised from the micro-micro to the macro-micro combination.

A Context-aware Tagging Model

In general, we have two classes of learning context, i.e. inner context and external context. Inner context is used to group and classify learning objects, i.e. the environment of one learning resource among others. For example, time, date, and device are external context, while the others of the aforementioned poem themes are inner context. The external context has been identified in mobile computing and e-learning domains [ADB*99, LiSe00], usually reflecting the surrounding learner's environment.

Tagging is effective for resource annotation. The miscellaneous property of tags in use is able to represent the great variety of learning resources. Thus, a context-aware tagging

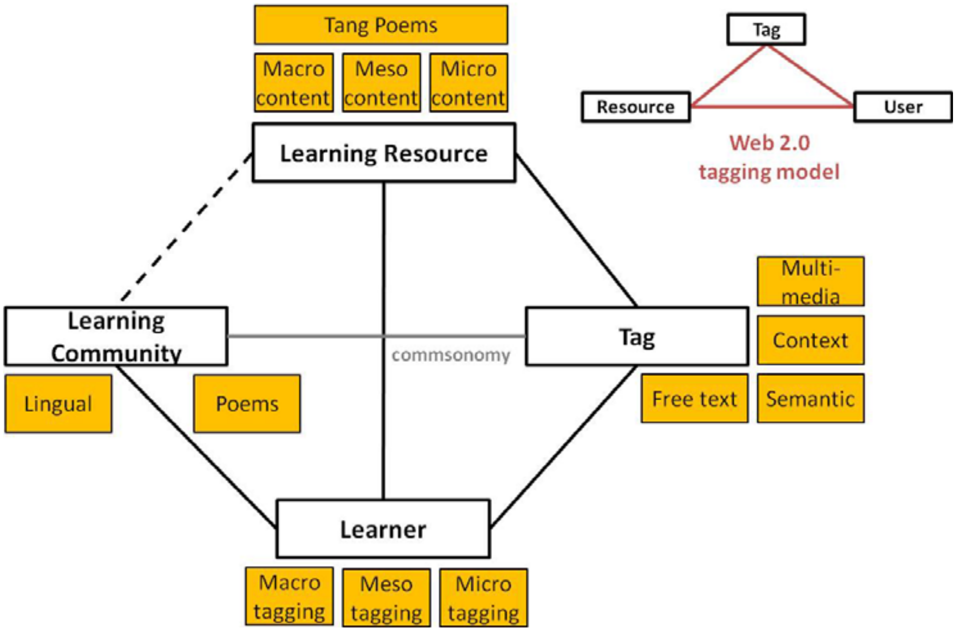

Figure 6.18: The context-aware tagging model for CCP

model is proposed for PLEs in order to organize learning resources, help learners learn and share within communities (see Figure 6.18). The usual Web 2.0 tagging model [MNBD06] has the components of *users*, *tags*, and *resources* as depicted in the upper-right part of Figure 6.18. The Web 2.0 tagging model (cf. Figure 4.9) is extended onto a PLE with enhanced context awareness of learning resources, learners, and communities.

In PLEs, the learners' community influences learning processes [Weng98]. The community aspect leads to the concept *commsonomy* saying that different user communities use different tags for the same resources. It refers to a group of tags or annotations for resources created, organized and shared by users in a user community [KCSp07]. More details are explained in Section 4.4. Learners tag learning resources on different levels including macro, meso and micro and learning resources also have this granularity.

Learners use tags represented in free or (semi-)controlled keyword vocabularies, or in semantic concepts and links. The context refers to the inner context of learning resources based on learning content analysis as well as the external context of learners' learning activities and their communities.

This tagging model is applied for language learning in the Chinese Classic Poetries PLE [CKG*09]. The learning content Tang Poems are decomposed into three content levels: macro, meso, and micro. Granularity on the content level helps learners organize their learning content and conduct game-based learning. The tagging activities are performed on Chinese Tang Poems at three levels based on the context-aware tagging model. For example, learners may learn CCP via CCP-related videos. *Micro tagging* is suitable for a single

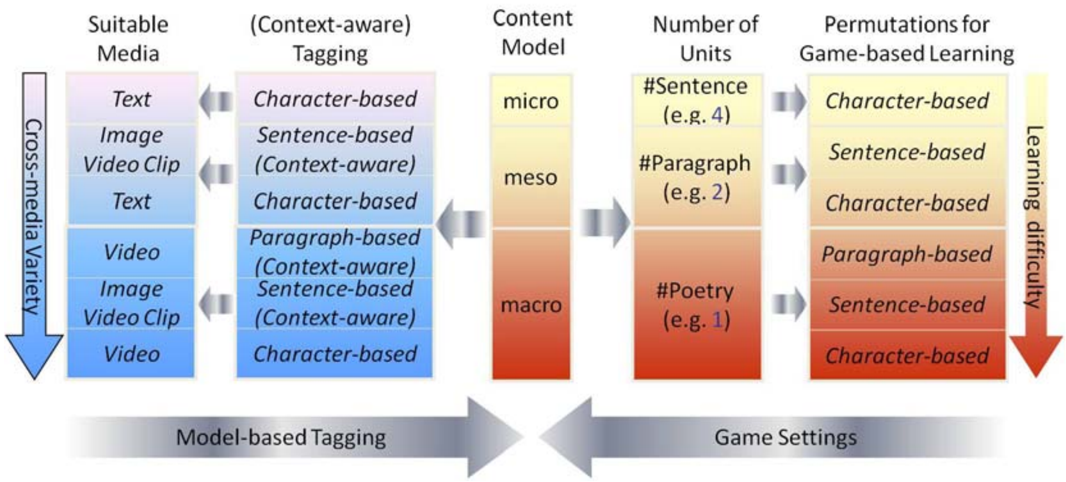

Figure 6.19: Macro, meso, and micro operations in game settings

word or character. A single frame of video is often tagged. *Meso tagging* is performed on sentence or paragraph level. Video clips of a duration are often tagged with more than one tags. *Macro tagging* is applied on paragraphs or whole poems. The whole video of a poem may include meso and micro tagging methods.

In addition, performing these three level content operations, users can learn CCP by playing games. A game setting can be specified based on the permutation operations on micro, meso, and macro levels (see Figure 6.19).

Implementation

Based on the relational data model, the realization of the prototype CCPLE focuses on the learner communities' requirements in order to help users learn CCP. CCPLE is implemented in Java to achieve portability. Educational gaming is one of the most important features in CCPLE. Users learn CCP via pre-selecting the game operations and obtain CCP knowledge by playing the game (see Figure 6.20). A set of Google Web Toolkit (GWT) tools is applied to support user interaction well.

GWT is an open source Java software development framework for web application development. It is featured with a Java-to-JavaScript-Compiler, so that the whole realization of both client and server side uses Java. It allows web developers to create Ajax applications in Java. GWT based applications are supported automatically in various Web browsers. GWT Tooling is a set of Eclipse plug-ins to simplify the development of GWT applications with Eclipse. GWT Tooling supports Eclipse Dynamic Web projects for traditional Java EE development as well as Java projects on the server side.

GWT Ext is a powerful widget library that provides rich widgets like grid with sort, paging and filtering, trees with drag & drop support and so on. The Ext JS is a cross-browser

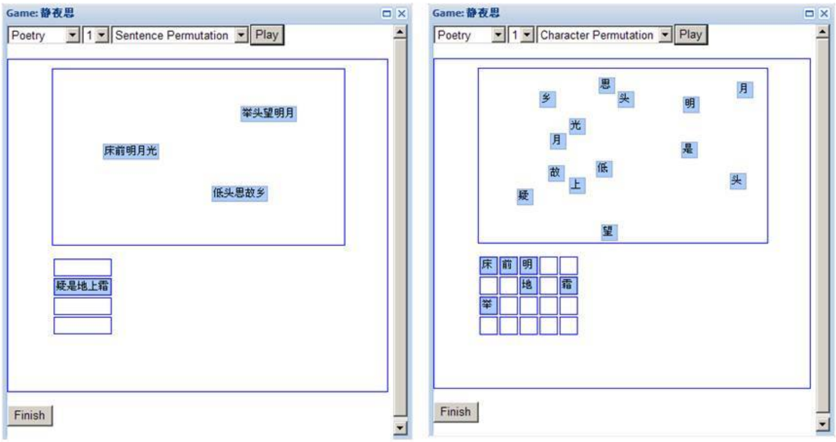

Figure 6.20: The CCPLE Screenshots of game-based CCP learning based on the multi-granular tagging model

JavaScript library with a host of rich widgets and components for building rich Internet applications. GWT-Ext library helps tie together the functionality of the GWT and the widgets available in the Ext JS JavaScript library. Since GWT-Ext wraps Ext JS, the Ext JS library is also required as precondition for using GWT-Ext. GWT-DnD is a library providing easy-to-use drag & drop capabilities to GWT applications. Though GWT-Ext provides also some drag & drop support, but mainly for tree widget, while GWT-DnD makes the most widgets be able to be dragged. The database on the back-end is Oracle 10g database which supports Unicode very well. The GWT Remote Procedure Call (RPC) mechanism is employed to enable the client side to invoke codes on the server side.

In CCPLE, users can upload poems with metadata and multimedia such as videos about the poem or various translation versions which are all stored in the database. Learner-generated poems can be searched and selected for learning by gaming. The game difficulty can be chosen with the flexible combination of content scales and operation scales in order to match users' learning profiles. The multi-granular tagging approach is beneficial to CCPLE.

After learners finish playing a game session, they can get feedback from the platform what learning achievement they have obtained. All achievement results are also traced and displayed in a grid panel. Learners' user names, game difficulty levels, and time for accomplishing games are listed to the learner community.

Evaluation

The CCPLE has been tested with nearly 50 people with different educational background. The test learners filled in the questionnaires after the evaluation period. Seventeen questionnaires are returned. Besides the language, lacking experience with Web 2.0 technologies is still a barrier, even among computer science students. Among those, fourteen are native Chinese speakers and seven of them have also learned CCP before. Interestingly, fourteen had never used a Chinese language learning platform before, and twelve even had never used an e-learning platform at all. Fourteen learners had learned about the Web 2.0 but only 8 had ever used Web 2.0 tools, but also for purposes different form learning. The functionality of the prototype is limited, so learners expect more new functions available in future. Some of them would like to produce video or flash applications for CCP themselves.

Editing multimedia for CCP is a tedious process and not supported by any learning platform so far. Usually, a video consists of a meaningful animation of the content, a high-quality audio recording of the citation of the poem and some appropriate music tracks. Since it has not been well tested to apply CCPLE for learning activities in communities, future research will cover community-based evaluation of learning success. But, for this evaluation we need access more learning communities.

More Web 2.0 features such as tagging, rating, and recommendations need be implemented in CCPLE. The internationalization of the platform should be increased via multi-language user interfaces. Learners can also share poetry or classical text in other languages and of other countries or regions in this environment. Deployment on various mobile platforms such as Android smartphones is still challenging. At the same time, a great amount of learner generated poetry content will lead to some uncertainty of learning content quality as well as poetry interpretation. This needs to be evaluated and tackled systematically, too. CCPLE services are planned to be integrated into the new EU large-scale integrating project Responsive Open Learning Environments (ROLE). The mission of ROLE is to support learners with simple means for building a custom personal learning environment without much prior knowledge. Support is provided through automatic suggestions of suitable tools and services respecting to preferences, learning goals, knowledge, etc.

Uncertainty Handling

This prototype targets learner communities for technology-enhanced learning. It aims at poem learning with enhanced semantic content. Classical Chinese Poetry has its rich and uncertain semantic. Various tagging approaches are applied to help learners master the learning content. Granularity tagging approach is realized through tagging a poem on the micro, meso, and macro content level.

CCPLE and SeViAnno have some common concepts and realization ideas. They focus on different application domains. An extended community operation in CCPLE is game design and realization according to the granular tagging model. Uncertainty reduction also occurs in the game-based learning processes.

6.4 Community Services

The conceptual age of technology is defined by cognitive and creative assets include design, storytelling, artistry, empathy, play, and emotion [Pink05]. Storytelling is listed as one of these crucial means to state the new era. The main conceptual approaches related to storytelling have been discussed in Chapter 5. Here, the storytelling systems YouTell on the Web 2.0 and Mobile Campfire for smartphones are discussed on the technical implementation levels.

6.4.1 YouTell: The Storytelling System

YouTell is designed and realized with Web 2.0 services for community-based storytelling using story templates. Professional communities' requirements are considered specially.

Architecture and Implementation

YouTell storytelling is featured with a role model for storytelling, the tagging concepts, the profile-based story search approach, and the expert finding mechanism. The prototype evaluation results show that the usefulness and performance in profile based story search as well as expert finding mechanism. Generated stories have been further applied to create educational games in order to train the professional communities.

An overall architecture of YouTell has been developed based on the Virtual Campfire architecture, as illustrated in Figure 6.21 [CKMa08]. The Storytelling Services announced in the Virtual Campfire architecture are focused on and extended. Accordingly, the (mobile) interface parts are extended with storytelling functionality such as story construction, story upload, and story search. YouTell is realized as a client/server system and is integrated in the LAS server [SKJR06] implemented in Java. The client, implemented as a web service, communicates via the HTTP protocol with the LAS server by invoking service methods. The LAS server handles the user management and all database interactions. New services like the expert, mailbox, YouTell user and storytelling services extend the basic LAS features and fulfill all functionality needed by YouTell.

The storytelling service includes methods for the management of story projects and searching for stories. The expert service contains functions for computation and management of the expert data vectors. The mailbox service manages the mailbox system. The YouTell user service extends the LAS user service and offers the possibility to add and edit user specific data.

In addition, YouTell needs several different servers to work properly. The client system communicates via the HTTP protocol with an Apache tomcat server. Their Servlets and JSPs are executed for the user interface of YouTell (see Figure 6.22). In YouTell the storytelling board is integrated with Java applets which run on the client. All media of the YouTell community is stored on a FTP server. The communication with the used databases (eXist and DB2) is realized by the LAS server.

Based on the story model in entity relationship diagram proposed in Section 5.2.1, YouTell users create a story project and invite other YouTell members to join this story project

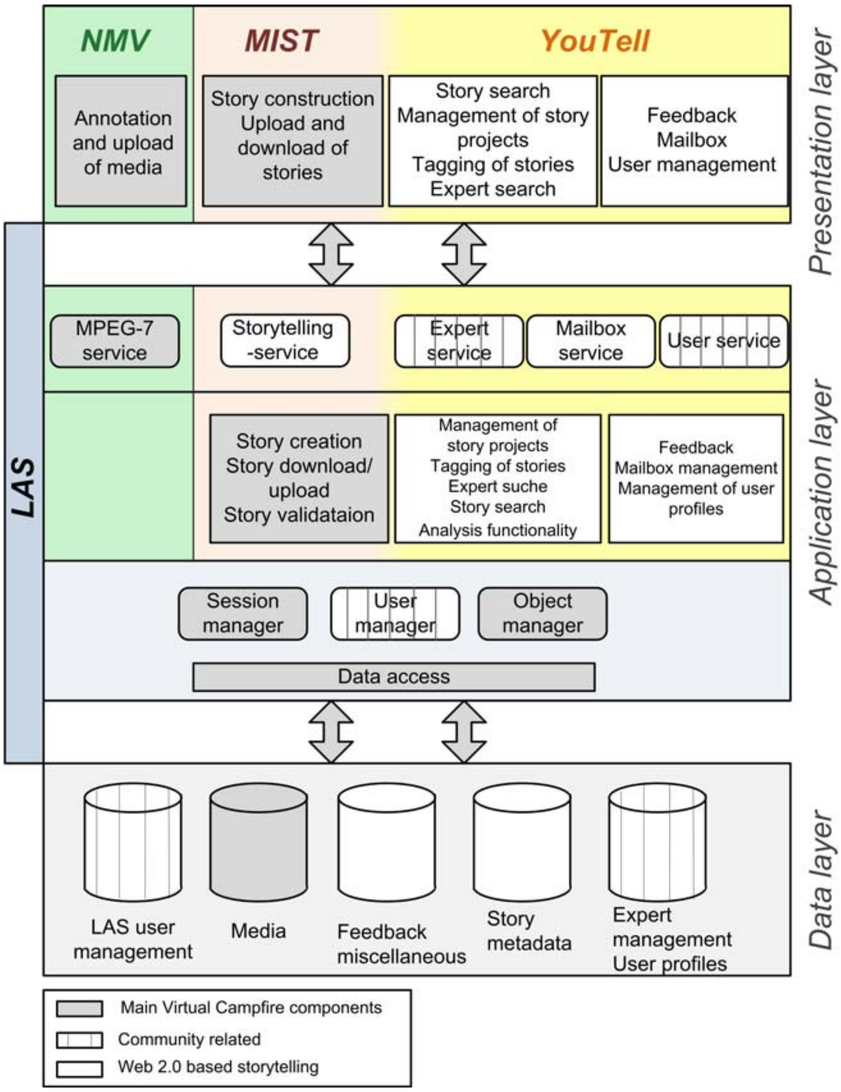

Figure 6.21: System architecture of YouTell [CKMa08]

before creating a story. Every team member is assigned to one producer role at least. Every YouTell user can tag stories to describe the related content. A multigranular semantic tagging approach is employed. Besides, users' rating and viewing activities on stories are also recorded. As depicted in Figure 6.23, a YouTell story is described with tags, rated by users. The popularity is also reflected by the viewing count.

Template-based Storytelling for YouTell

The system architecture of a template-based storytelling platform called *YouTell TE* is extended on the *YouTell* architecture. According to the entity relationship diagram, several

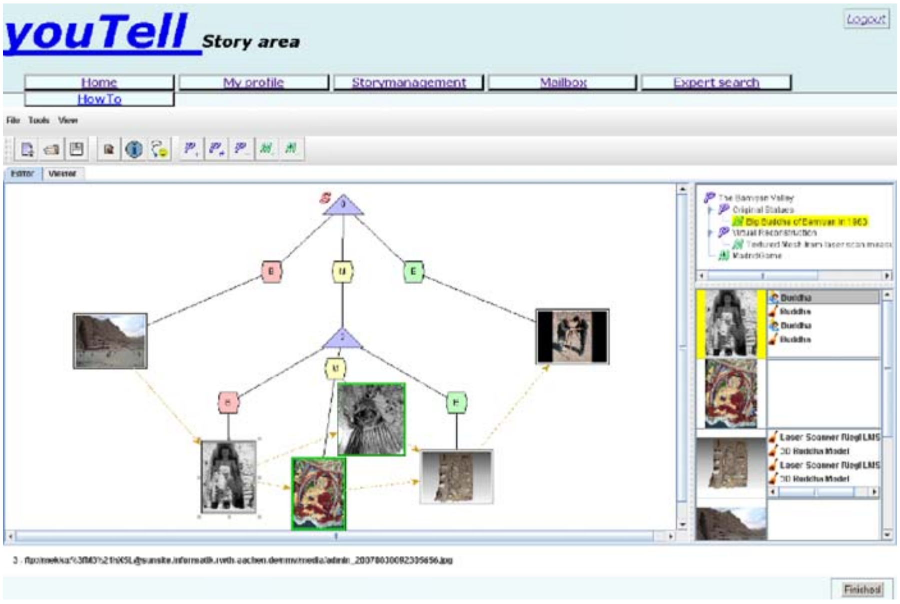

Figure 6.22: YouTell screenshots and functionality description

Figure 6.23: Information board of a YouTell story

databases are used together at the data layer. The data repository consists of story databases for stories, story projects, and multimedia. Story user profiles including their role information are stored in the user database. Story templates and metadata information are stored in the XML database.

At the application level, the LAS Server [SKJR06] is employed for *YouTell TE* to make good use of a set of existing community functionalities. The services can be easily added onto server within the XML configuration file as listed in Listing 7.

```
<las>
  <components/>
  <services>
      <element code="templateengine"
      start="true" fromjar="true">
   <!-- Dependencies to other
   services and components -->
   <dependsfrom element="db2-component" />
   <!-- Used libraries -->
     <usedlib name="template_engine" />
     <usedlib name="graphml" />
     <usedlib name="youtell_tools" />
   </element>
  </services>
  <connectors/>
</las>
```

Listing 7: YouTell service configuration in XML

Two new services are implemented in LAS: the template engine service and the template engine story service. The template engine service is the new core service. This service is invoked when users want to manipulate the templates, e.g. edit the templates or create a mashup. And since editing the template is a more or less straightforward operation, combining two of them can be performed in several ways.

The presentation layer is an interactive application running in Web browsers on the client side. Ajax technologies for the Web 2.0 are applied for the story template operations and the template-based story creation. Story users open a story board for a story project, select, create, adapt or mash up story templates. Based on the template, stories can be created via adding and removing media to each node of the template graph.

The user interface is designed with the principles of intuitiveness and easiness for use (see Figure 6.24). Possible options for the users are a template previewer, an editor of the selected template, and the mashup operator. The preview function gives users access to the template pool. The available option *view template* is realized in Java Server Page with the Ajax technology based on dojo framework for graph visualization. The main interface depicted in Figure 6.24 is built on a dojo GraphCanvas widget. Another available option is *edit template* to create a new template or adapt the existing one by the users. In the *edit* mode modifications to graph and renaming of the graph are possible. To create a new node, the user can click the screen to get a list of the new shapes. When the user adds two or more nodes to the screen, he/she can connect them with an edge via dragging the mouse pointer

Figure 6.24: The story template editor of YouTell

from first node to the second one. The loop edge (edge with the same source and target node) can be created in the similar way, it is necessary to drag the mouse from one part of the shape node to the other. The process of creating the new graph is also enriched with the options for the user to change the shape nodes of the graph. The mashup operation is done based on the graph operations introduced in Section 5.2.4.

Users are able to zoom in and out, drag the graph on the display and see the node information by positioning the mouse pointer over a node without reloading the Web page. This operation is performed either by mouse buttons and the scroll bar, or by the menu buttons, which are marked in Figure 6.24. A display navigation mode is available for users to drag the mouse and set the view to a certain sub part of the graph. The user is able to create a new story using a selected template which was created, adapted, and merged with another template previously.

Behind the user interface for the storytellers, the templates represented in graphs are edited and adapted. The realization of the mashup operation is a graph merging process, where the series and parallel composition operations introduced in Section 5.2.4 are applied. If two templates have the equal number of nodes, the parallel composition is applied as a default. In addition, more graph operations can be applied (see Figure 6.24 right). The rooted product operation is applied at first. Then a parallel composition is applied. There will be two parallel stories with a common begin and end. The story users can decide to choose from which point of the story (from which node) to make a connection to the following node of the other story. Another case is that the number of the nodes of the two templates differs. As the first step, the rooted product operation is applied after users' selection, before the parallel composition is applied. Or the parallel composition is applied as the first step. After that, a result from this composition will be added to the rest not-in-use nodes from the longer graph. They are added in the series composition way.

Users can select an arbitrary node from the graph and from the context menu, and add multimedia by selecting the option “Add media”. The first active tab is called “Keyword search”. In the available textbox users can start typing the keywords for media search. With the “Tab” key or pressing the “ok” button the results are displayed in the “Multiselect” listbox down from the textbox. The Ajax function creating “XMLHttpRequest” object is applied for this process. In this asynchronous way a Java function is called and the results are returned without reloading the current page.

The templates in the application are presented in graphs specified in GraphML. GraphML is a comprehensive and easy-to-use file format for graphs. It consists of a language core to describe the structural properties of a graph and a flexible extension mechanism to add application-specific data. XML beans are applied for the GraphML documents and the XML schema for the template metadata is designed. XML beans libraries help with converting XML file formats to Java classes, which simplifies a number of different operations and manipulations over the XML files.

Unlike many other file formats for graphs, GraphML does not use a customized syntax but the generic XML format. Hence, it is suitable for all kinds of service generating, archiving, or processing graphs. A GraphML document consists of a <graphml> element and a set of sub elements: <graph>, <node>, and <edge>. Each node has an identifier which must be unique within the entire document. The identifier of a node, the XML-Attribute “id”, is used to declare a GraphML attribute with its node scope. The values comprise structured data that encodes the positional, dimensional, and graphical attributes. Edges with only one endpoint, also called loops, self loops, or reflexive edges, are defined by having the same value for the source and target. XML simplifies also the mapping and merge of different story templates. For instance, Listing 8 represents the merge of the MOD story pattern with the problem-solution pattern.

```
  <?xml version="1.0" encoding="utf-8" ?>
- <xs:schema targetNamespace="http://www-i5.
informatik.rwth-aachen.de/modstory"
xmlns:xs="http://www.w3.org/2001/XMLSchema"
xmlns:mod="http://www-i5.informatik.
rwth-aachen.de/modstory"
elementFormDefault="qualified"
attributeFormDefault="unqualified">

+ <xs:element name="story">
  <xs:element name="problem"
      type="mod:problemType" />

+ <xs:complexType name="csuType">
+ <xs:complexType name="problemType">
  </xs:schema>
```

Listing 8: Merge of story templates

Evaluation of YouTell

The evaluation is based on the analysis of tags the test users have employed for different media and media collections, here multimedia stories. The expert finding algorithm delivers user/tag pairs with an expert value lying between one and zero. The value distribution has been analyzed in order to evaluate the algorithm.

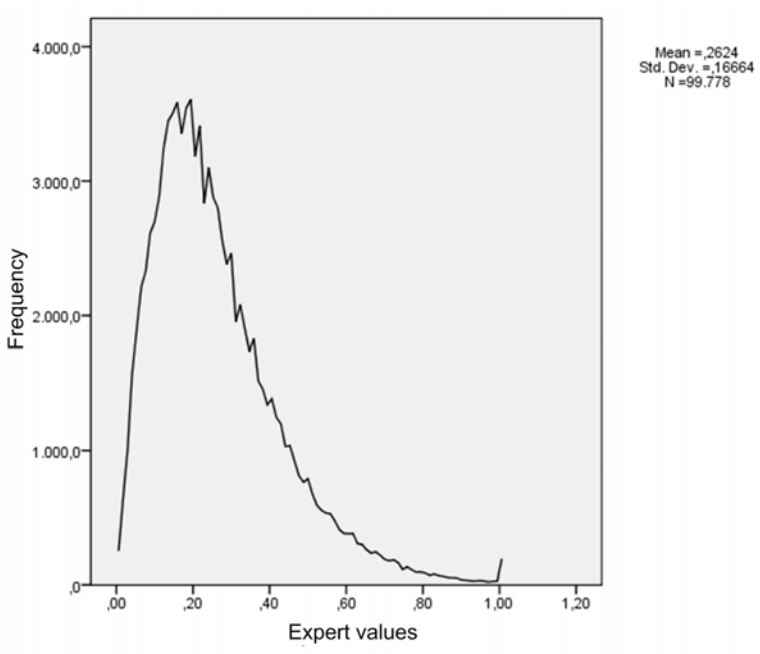

Figure 6.25: Distribution of expert knowledge

In Figure 6.25 the distribution of the expert values is depicted. For every number on the x-axis the frequency of user/tag pairs with an appropriate expert value is denoted. Figure 6.26 shows the same values separated by the singular tags.

So both figures show that the expert knowledge distribution is approximately normally distributed. Because the test data is predominantly normally distributed this result is expected. In Figure 6.25 the expert value 1 has a peak which seems to be unusual at first glance. This can be explained by the used normalization: After computing the data vectors they will be normalized in the range from 0 to 1 separated by the tags.

This approach establishes the possibility to represent the knowledge assigned to a particular tag within the YouTell community. Figure 6.26 shows that the distinct knowledge function differs. This implies that the knowledge about particular topics is different within the YouTell test community.

In addition to classification of the users' knowledge, the expert finding algorithm delivers a measurement for analyzing the community knowledge. The results show that the number of

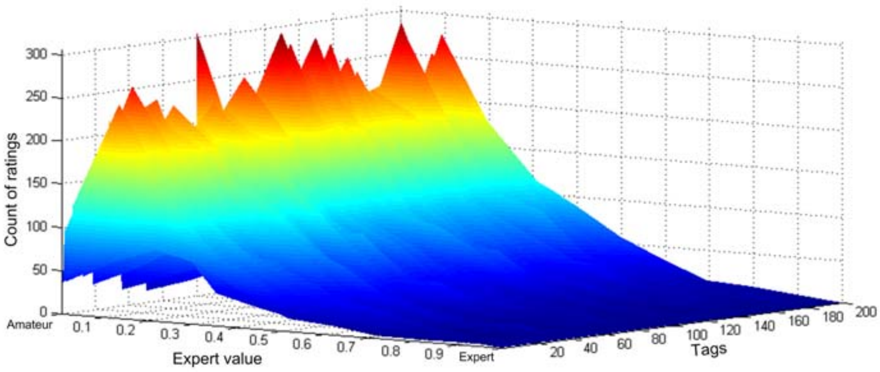

Figure 6.26: Distribution of expert knowledge according to tags

tags or keywords in use decreases as the users attain more expertise knowledge within a community of practice.

Uncertainty Handling

Annotation is carried out on multimedia and stories with granularity. The effectiveness of storytelling for information processing has been stressed in previous Chapter 3 and Chapter 5. Above all, community-based storytelling as an important multimedia operation as well as a practice is able to involve and develop communities of different user roles.

On the one hand, the tags used by amateurs and experts show differences, which is applicable for uncertainty reduction. On the other hand, experts are not born experts and can be cultivated in communities of practices. Communities of practices possess a large amount of multimedia as well as the valuable resources of users' community-based activities. Among them, storytelling is an effective uncertainty-reduction practice for information processing in communities. Users are offered with story templates, which also help users to organize multimedia in a better way.

Multimedia storytelling enables users to share a collection of multimedia for a common purpose, instead of handling individual multimedia items. It provides a potential approach to handling multimedia uncertainty.

6.4.2 Mobile Campfire: Mobile Multimedia Management

A mobile application of YouTell is developed on iPhone and other smartphones for mobile communities. Mobile Campfire is an extension of YouTell to enhance application mobility.

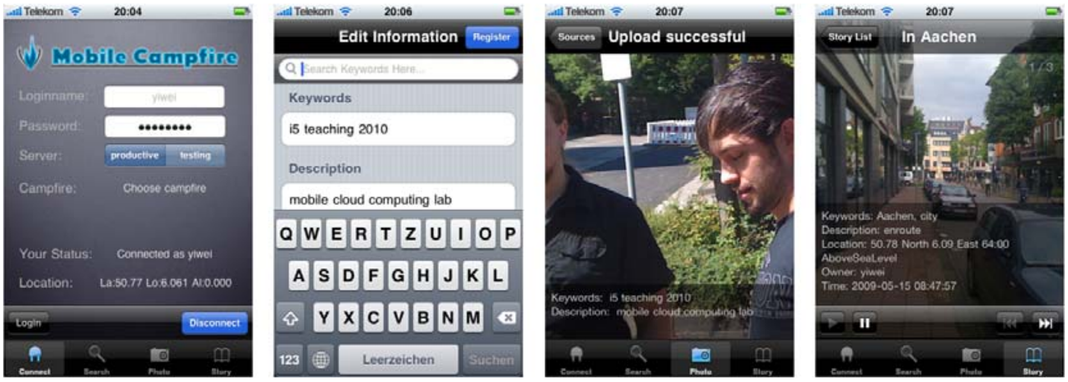

Figure 6.27: Mobile Campfire screenshots

Design and Realization

Through Mobile Campfire mobile users are able to upload images using the integrated camera or the album on the storage. They are asked to annotate media with free text tags, the MPEG-7 metadata standard based tags and other descriptions. Multimedia files in the data repository can be searched and retrieved according to the given tags later.

Besides browsing individual multimedia items, users can access and share multimedia by stories. In short, main features related to media search are a page-based multimedia result list, scrollable original image preview, and metadata panel which shows tags, description and MPEG-7 semantic descriptions. The features related to media creation include getting photos from camera or library, annotation of multimedia, and generation of MPEG-7 compatible semantic descriptions. Keywords can be also input by auto completion, which is especially important for mobile interface. The story browser also integrates a video player with a metadata information panel. Stories can be created from the YouTell platform and exported into Mobile Campfire in the format of SMIL (Synchronized Multimedia Integration Language) . All data communication is based on the HTTP protocol and connections are set up to LAS server framework of Virtual Campfire.

Figure 6.27 depicts a set of main screenshots of the Mobile Campfire including the user management for professional communities, semantic and context management for multimedia, and storytelling on mobile platforms.

Uncertainty Handling

Related uncertainty issues, the context information of device profiles is applied to avoid significant mismatches between mobile information providers and mobile devices. In order to make users access and display information appropriately, media adaptation to device preferences is necessary for mobile information systems. Device-context based multimedia adaptation contributes to the concept of *Universal Media Access (UMA)* [MGF*02, HeHa04].

Context-aware tagging in mobile environments enhances multimedia semantics via context information.

6.5 Summary of the Validation

The Virtual Campfire scenario consists of several mobile community information system applications with different foci spanning from context, semantics, to community uncertainty management. These applications have been applied in the domains of cultural heritage management and technology enhanced learning. The prototypes validate the soundness of the concepts.

These (mobile) community information systems employ a great amount of multimedia with rich semantics. Their adaptive applications also run on mobile platforms involving context information and metadata. Communities of practice are reflected and supported well in these applications.

Since the development period of all these applications has spanned for several years within this dissertation research period, the problems of employing latest technology against handling legacy systems and dealing with data migration have been acute. Various mobile devices have also encountered different development phases from wireless network technologies to various mobile operating systems.

According to the related aspects of *uncertainty 2.0* (cf. Chapter 2), the validation is conducted both on the multimedia annotation and community-based storytelling approaches (cf. Chapter 4 and Chapter 5). Table 6.2 gives a comparison of all Virtual Campfire prototypes. The marks "+" (plus) and "-" (minus) are used to show whether the sub categories of uncertainty 2.0 are related to each prototype respectively.

The prototypes are categorized in the three aspects: context, semantics, and community. The approaches to handling uncertainty also have the focus on the aforementioned aspects respectively. Selection of metadata standards and mapping among various metadata standards can enhance semantic richness and precision of expression. This semantization process is realized through interactive multimedia annotation (see SeViAnno and ACIS). On the other hand, spatial search and other context-aware search enable users to better formulate multimedia queries (see ACIS and CAAS). Context modeling establishes a basis for further context reasoning. Various annotation approaches concluded in CCPLE facilitate the semantization and contextualization operations among multimedia, metadata, and communities of practice.

YouTell together with Mobile Campfire validates that storytelling is a complex multimedia operation taking place in communities of practice. Storytelling employs a great amount of multimedia and its metadata and stories with the attached multimedia and metadata. The storytelling process is an intensive procedure for the contextualization operation in communities of practice. Thus, the roles of users ranging from amateurs to experts play an

		CAAS	ACIS	SeViAnno	CCPLE	YouTell
Features		Context-aware MM search	GIS for CHM	Tagging	Tagging	Storytelling
Context	Geospatial	+	+	+	-	+
	Temporal	+	-	+	-	-
	Social/community	-	-	+	-	+
	Technical	+	-	+	-	+
	Approaches	Context modeling and context reasoning	GIS	Geo-tagging	Context-aware tagging	Mobile story sharing
Semantics	Domain	-	+	+	+	-
	Richness	-	+	+	+	-
	Precision	+	+	+	-	-
	Standard	+	+	+	-	+
	Approaches	//	Metadata standards of GIS, CHM, and MM	Expert tagging	Various tagging approaches	Story tagging
Community	Annotation	-	-	+	+	+
	Sharing	-	+	+	+	+
	Mobile	mobile client (J2ME)	Web browser	AnViAnno (Android phone)	Web browser	mobile Campfire (iPhone)
	Approaches	//	Community-based role model	User interface design, expert tagging	Community-based role model, multimedia games	Community-based role model, experts and amateurs

Table 6.2: A summary of Virtual Campfire prototype evaluation

important part in handling uncertainty. Experts use precise, semantic rich, and fewer tags or keywords than users with less expertise. Communities of practice cultivate the development of becoming experts to reduce multimedia uncertainty further.

Besides uncertainty handling, experiences with a variety of mobile and Web 2.0 platforms and technologies are useful and reflective for developing mobile community information system applications.

We may regard the present state of
the universe as the effect of its past
and the cause of its future.

Pierre Simon Laplace,
A Philosophical Essay on
Probabilities

Chapter 7

Conclusions and Future Work

Research on data uncertainty in mobile community information systems has a wide spectrum. In this dissertation, I have proposed a model to observe, describe, and handle uncertainty problems based on the aspects of multimedia semantics, context, and community. This research work paves the way to uncertainty management in mobile community information systems with new viewpoints, besides the existing uncertainty database solutions.

7.1 Summary of Results

Data uncertainty problems have many sources coming from data creation, management, and sharing processes. Three aspects of *semantics*, *context*, and *community* are put forward to observe, specify, describe, and handle the *uncertainty 2.0* problem in mobile community information systems.

The data uncertainty problem in mobile community information systems i.e. uncertainty 2.0 need be considered in the following three aspects:

- The context aspect covers geospatial, temporal, social, and technical context information of mobile multimedia;
- The semantic aspect covers domain, richness, precision, machine readability of mobile multimedia;
- The community aspect covers the whole community-driven media operations on mobile multimedia. These are multimedia creation, management, search & retrieval, sharing, and recommendation.

In this dissertation uncertainty 2.0 handling is advanced by continuous collaborative *semantization* and *contextualization* operations on mobile multimedia. Data uncertainty is reduced via the switch between multimedia semantics and context based on semantics and context mappings. These abstract processes are realized in multimedia annotation and storytelling, which further has developed and realized the media operations in the ATLAS media theory [Jaeg02, Span07, Klam10]: transcription, localization, and addressing.

Within the multimedia annotation approach, multimedia artifacts are transcribed in tags, and localized with contextual information. A new annotation approach, the multi-granular tagging model, is proposed. Being used together with several other existing annotation approaches, the semantization and contextualization processes of multimedia are supported. Commsonomy connects tags to communities tightly, which reduces uncertainty created by "amateurs" through communities.

Multimedia storytelling transcribes multimedia artifacts in non-linear stories addressed to story consumption context and user communities. Furthermore, multimedia storytelling provides communities of practice an appropriate media operation to create and consume Web and mobile multimedia.

The potential data uncertainty problem is reduced via this orchestration of media context-semantic management and the further annotation and storytelling processes. Both annotation and storytelling approaches depend on the user community who carries out these practices. Experts and amateurs play complementary roles in reducing data uncertainty, whereas uncertainty produced by amateurs can be removed by experts. Additionally, mappings between context and semantics need be specified according to different settings for avoiding data uncertainty. The same context may have different semantics in different domains. Extensions are supported to enrich the mapping model.

The validation of my uncertainty handling model has been achieved by technical realization of a set of mobile community information systems in the scenario Virtual Campfire within the German Excellence Research Cluster UMIC project. Uncertainty handling proves to be beyond merely a single process, because it consists of a series of semantization and contextualization processes taking place repeatedly. Moreover, uncertainty handling has established a framework to engineer these complex mobile community information systems for professional user communities. Semantics, context, and community uncertainty are considered in design and realization of mobile community information systems. Results show that users are supported with various multimedia tagging and storytelling operations to create, annotate, manage, and share media with less uncertainty. In the communities amateur users are able to develop their knowledge and skills, and to become experts in the related domains.

Along with the research on conceptual approaches and technical realization, three International Workshops on Story-Telling and Educational Games (STEG'08 - STEG'10) have been organized as an annual event to bring researcher communities on storytelling together. Open discussions and feedback have evaluated the storytelling approach well.

7.2 Open Issues

Uncertainty handling in mobile community information systems has been conducted based on the proposed model. Further research work can be carried out according to the results achieved in this dissertation. I classify the future research in the four research fields presented in Figure 1.1 in Chapter 1: multimedia semantics and context, community management, (mobile) multimedia annotation/tagging, and (mobile) storytelling and recommending experts. They have different foci ranging from models and basic approaches (the lower part) to multimedia information systems (the upper part), and from context and semantics (the left part) to community of practice (the right part).

For these four fields, the following future research work may be taken:

- Research of media operations on Web 2.0 related to multimedia semantics and context as well as community management: This dissertation has addressed that one type of community uncertainty is caused by inappropriate media operations. There exist various media operations such as comment, like, and share, Nevertheless, there exist various platforms which hosts different communities. Users encounter the uncertainty, when they are uncertain about which operations and which platforms they should choose at media creation and consumption. This problem has been tackled through systematic analysis and modeling of various operations. Further research could be conducted in methods to help users select certain media operations in certain user communities and platforms.
- Augmented reality tagging in the cloud computing related to (mobile) multimedia annotation/tagging: Tags have been applied to annotate online resources. This tagging activity can also be extended to the real world. Products in stores and books in libraries have been tagged with technologies such as RFID. With the emerging cloud computing technologies, the physical objects may be widely tagged by common user communities. The increasing tags may lead to more data uncertainty problems which require analysis and handling.
- Social network analysis for uncertainty handling related to (mobile) storytelling and recommending experts: Social network analysis (SNA) methods [BrEr05, Newm03] are applied to identify structures and patterns of large-scale network data. Uncertainty problem especially related to social network data can be analyzed and reduced via various clustering algorithms and centrality measure computation.

This dissertation research opens three future directions for mobile community information system development with regard to uncertainty 2.0 handling: convergence of web and mobile, mobile clouds, and mobile knowledge management.

Convergence of web and mobile

The goal is to network every virtual and physical piece of information via a set of efficient means. People are connected on social network sites to communicate among themselves, using various widgets running on smartphones when they are en route. Locations are connected to users via location-based services and GPS technologies. Various map-based mashups try to replace conventional geographic information systems (GIS). Environments and physical objects are connected to users by means of advanced 3D technologies and augmented reality.

Where do community information systems go? Ten years ago, every community information system connected to its own databases and builds their own tools for information browsing, collection, emails, forums, and community communication. With the introduction of OpenSocial, social network sites, e.g. FaceBook, Twitter, LinkedIn are available and easily integrated into various community information systems. People can make use of these free services and host their blogs to reach a bigger community. Web sites and platforms can well survive, if they are connected with those big SNS. Community information system design has changed the focus on complete design and integration of all useful tools and functions. Nowadays, how the systems make open access to the big SNS is more challenging on the one hand. On the other hand, as demonstrated in the Web 2.0 principle "data as the next Intel Inside", data analysis, privacy, and security play a crucial role to reduce uncertainty.

Mobile clouds

Advanced technologies in cloud computing or flash disks to quick access data stored on hard disks are bringing new experiences to ubiquitous media accesses. Tagging enhances information consumption and sharing across media. Not only semantics but also context information is embedded in tags. The anarchy of the ways that tags are created and applied brings much freedom or ubiquity to information. Accordingly, storage is freed by future cloud computing technologies.

Mobile applications will be an extension for pervasive communities based on Web. Mobile Internet and mobile applications run on different device levels, from desktop, laptop/notebook, tablet PC, netbook, ebook, iPad till various smartphones. Screen sizes and computation capabilities differ among them, while applications are unified to some extents. Users will not care about or notice what kind of devices they have in the hand. It is important for mobile users to have an interface to access various Internet services with multimedia data provision in the cloud. Accordingly, mobile users have requirements on multimedia with reduced uncertainty.

Knowledge management

New York Times will stop printing edition in 2015, as announced in October of 2010[1]. Google is digitizing books in more and more libraries worldwide. People become aware of breaking news from Twitter much more quickly than radio broadcasting. Movie stars'

[1]http://www.huffingtonpost.com/henry-blodget/sulzberger-concedes-we-wi_b_710778.html

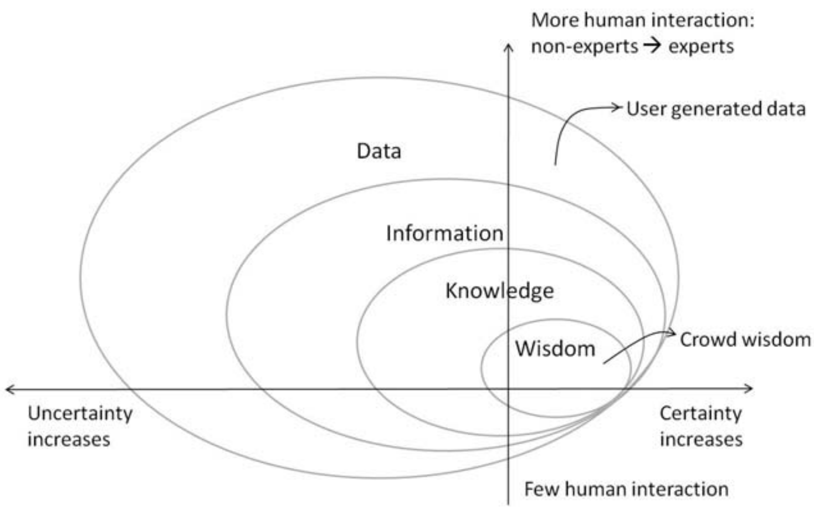

Figure 7.1: Uncertainty and human interaction in the data information knowledge and wisdom chain (extended from [DaPr98])

blogs may be followed by many fans. Professional blogs are replacing traditional media for knowledge distribution. Although already since 1970's a new era is announced, we are still astonished and inspired by the rapid development in information technologies in recent years. Exactly, this new era is the *Information Age*. Before, the *Industrial Age* enabled massive production of industrial products. The result was an increasing number of consumer and industrial products. The changeover happened in the middle of 20th century, while research results of one discipline began to influence outcome in other disciplines [Druc99]. On the one hand, this interdisciplinary cooperation is empowered by information. On the other hand, high degree of interdisciplinarity leads to great and rapid progresses in information technology development.

Figure 7.1 depicts the role which uncertainty issues play in knowledge management. I extend it with two axises, the uncertainty degree and human's interaction degree. Data is not information and knowledge is not wisdom. Experts' increasing interaction on data enriches wisdom formulation. In the contemporary *Information Age*, the forming-up of wisdom can be better tracked in people's condensation processes of data, information, and knowledge. Advanced mobile and web technologies are applied in and changing people's multimedia creation, management, and sharing processes which are also people's knowledge management processes.

I believe that successful mobile community information systems are heading for creation, management, and sharing multimedia with less uncertainty for user communities.

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Appendix A

List of Abbreviations

Abbreviation	Description	First mentioned	
ACDC	Aachen Center for Documentation and Conservation	p.	154
ACIS	Afghan Community Information System for Cultural Heritage Management	p.	132
AJAX	asynchronous JavaScript and XML	p.	39
ANSI	American National Standards Institute	p.	50
CCP	Classical Chinese Poetry	p.	132
CCPLE	Classical Chinese Poetry Personal Learning Environment	p.	132
CHM	Cultural Heritage Management	p.	51
CIDOC	The International Committee for Documentation	p.	53
CoP	Communities of Practice	p.	4
DC	Dublin Core	p.	36
FISH	Forum on Information Standards in Heritage	p.	54
GIS	Geographic Information System	p.	9
GPS	Global Positioning System	p.	22
GraphML	Graph Markup Language	p.	169
GSDI	Global Spatial Data Infrastructure	p.	51
GWT	Google Web Toolkit	p.	161
HTML	Hypertext Markup Language	p.	39
HTTP	Hypertext Transfer Protocol	p.	41
ICOMOS	International Council on Monuments and Sites	p.	141
IDE	Integrated Development Environment	p.	152
IEEE	Institute of Electric and Electronic Engineers	p.	50

INSPIRE	Infrastructure for Spatial Information in Europe	p.	51
ISO	Organization for Standardization	p.	50
J2ME	Java 2 Micro Edition	p.	138
LAS	Lightweight Application Server	p.	131
MIDAS	The Monument Inventory Data Standard	p.	54
MOD	Movement Oriented Design	p.	60
MPEG-7	Multimedia Content Description Interface	p.	52
NFC	Near Field Communication	p.	46
OASIS	Organization for the Advancement of Structured Information Standards	p.	50
OGC	Open Geospatial Consortium	p.	51
OMA	Open Mobile Alliance	p.	47
OWL	Web Ontology Language	p.	36
PDF	Probabilistic Density Function	p.	12
PLE	Personal Learning Environment	p.	157
QoC	Quality of Context	p.	19
QoI	Quality of Information	p.	19
RDF	Resource Description Framework	p.	36
RFID	Radio-Frequency Identification	p.	46
RIA	Rich Internet Applications	p.	39
ROLE	Responsive Open Learning Environments	p.	163
RPC	Remote Procedure Call	p.	162
RSS	Really Simple Syndication	p.	34
RTMP	Real Time Messaging Protocol	p.	154
RTP	Real Time Transport Protocol	p.	154
RTSP	Real Time Streaming Protocol	p.	154
SECI	Socialization, Externalization, Internalization, and Combination (Knowledge creation operations)	p.	28
SDTS	Spatial Data Transfer Standard	p.	13
SeViAnno	Semantic Video Annotator	p.	132
SMIL	Synchronized Multimedia Integration Language	p.	172
SNA	Social Network Analysis	p.	177
SNS	Social Network Site	p.	35
SOA	Service Oriented Architecture	p.	40
SOAP	Simple Object Access Protocol	p.	41

SPARQL	SPARQL Protocol and RDF Query Language	p.	80
STEG	International Workshop on Storytelling and Educational Games	p.	176
UMA	Universal Media Access	p.	172
UMIC	Ultra High-Speed Mobile Information and Communication	p.	7
UNESCO	United Nations Educational, Scientific and Cultural Organization	p.	141
VC	Virtual Campfire	p.	8
WSDL	Web Service Description Language	p.	41
WWW	World Wide Web	p.	49
W3C	World Wide Web Consortium	p.	41
XML	Extensible Markup Language	p.	36
XMPP	Extensible Messaging and Presence Protocol	p.	48

Curriculum Vitae

Name:	Yiwei Cao
Birthday:	January 6, 1976
Birth Place:	Shanghai
Address:	Mariahilfstr. 2a 52062 Aachen Phone: 0179 7522066 Email: cao@dbis.rwth-aachen.de
School:	September 1982 - August 1987: Primary School at Dantu Road, Shanghai September 1987 - August 1993: The First Middle School Attached to East China Normal University, Shanghai
Language Skills:	Chinese (native) English (fluent) German (fluent)
Academic Education:	September 1993 - August 1998: Tongji University, Shanghai Major in Architecture July 1998: Bachelor of Architecture October 2000 - March 2005: RWTH Aachen University Major in Computer Science Minor in Business Administration July 2002: Vordiplom of Computer Science March 17, 2005: Diplom of Computer Science
Professions:	Research assistant at Lehrstuhl für Informatik 5 (Databases and Information Systems, Prof. Dr. M. Jarke since September 2005; participating in German Excellence Researche Cluster "UMIC" since November 2006, DAAD Project "IKYDA" from 2009 to 2010, EU Lifelong Learning Project "TeLLNet" since 2010.